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TROPICAL AGRICULTURE is published at the Imperial College of Tropical Agriculture St Augustine, Trinidad, West Indies, at the end of the third week of the month preceding the one of issue. Advertisement rates can be obtained at the College from the Editor, or from the Secretary of the College, 14, Trinity Square, London, E.C. 3, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed in signed articles are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

COLD STORAGE PROBLEMS.

SUCCESS, be it ever so pronounced, is but a mile-stone on the great road of progress and a stimulus to further effort towards a goal which lies ever beyond. The years have witnessed in the rapid march of science in all her branches, her rapidly increasing influence in the world of commerce and industry—in short, the improvement and further development of the existing and the birth of the new. During the past decade, amazing results have been achieved in experimental work on the mechanical production of low temperatures and the countless applications, biological and otherwise, of refrigeration generally mark it as truly one of the industrial successes of the age.

Not the least important and perhaps the most readily appreciated of these applications is the cold storage of perishable animal and vegetable food products; its economic importance and the enthusiastic recommendation of the medical fraternity have brought it still further into the limelight. Low temperatures militate against the activities of putrefactive organisms and fungal growth generally, so that from the standpoint of ordinary domestic hygiene, cold storage has proved a boon. With regard to its economic importance it must be readily apparent that in the case of a fruit which has a short season annually, it is of tremendous importance to the producer to be able to delay senescence. Instead of the low prices of the "glut" season, a better figure is obtained later, when, after a period of storage, the fruit is retailed, the consumer being content to meet the extra cost for the privilege of obtaining fresh fruit in the off season. A still more important development of cold storage experiments, from the economic point of view, is the question of induced winter hardiness in plants. In the Northern Countries growers of wheat and lucerne—staple crops, one for the supply of bread and the latter for stock—are faced with the hazard of great losses during severe winters. Harvey, however, has shown conclusively that frost tolerance or resistance to winter injury may be induced, that is, if a young seedling be introduced by a series of gradations to the low temperatures it may be schooled to withstand the rigours of a severe winter—the importance of this work to countries like Canada and the United States of America needs no further comment here.

The present gratifying state of affairs in the matter of food storage is the outcome of a thoroughly scientific attack on the problem from all possible avenues of approach. The transport of foodstuffs has called for a considerable amount of research work. Investigators have travelled many thousands of miles with experimental cargoes of fruit: by means of suitable distant-reading and recording apparatus several interesting facts have been brought to light. The self-heating of fruit in bulk, the conduction of heat from the ship into the insulated holds along beams, &c., projecting through the insulated walls, and the leaks through hatchways are vitally important considerations since they govern the two great variables of the storage chamber, viz.: temperature and composition of the atmosphere—factors, in a large measure, responsible for the condition and well-being of the stored fruit. The slightest hitch in the efficiency of the refrigerating engine, is, in view of the considerable amount of heat evolved, a serious matter, introducing as it does the age-old vicious circle. A rise in temperature stimulates increased respiratory activity; with increased respiration further heat is evolved and so on. These difficulties of transport have been greatly minimised by pre-cooling the fruit in harbour pre-cooling stations immediately prior to shipment, by the use of "dunnage" on crates to allow of the passage of cold currents between successive tiers of crates, by improved ventilation and the use of refrigerating engines of greater efficiency.

Numerous investigations have been carried out with a view to determining the chemical changes taking place during the ripening, the optimum conditions of temperature and composition of the atmosphere, the effect of pre-storage factors of nutrition—soil and climate—on the length of storage life and keeping quality generally. With each particular commodity, these determinations must be made if consistent successful storage from season to season is expected.

Foodstuffs of animal origin have likewise engaged a considerable amount of attention. In recent years numerous new processes for the preservation of meat, both by cold storage and by other means, such as arterial injections with innocuous substances, have been elaborated. Experimental work has proceeded with a view to determining the precise conditions ensuring the reversibility of the freezing-thawing cycle. It is now well established that freezing should be rapid to avoid the formation of large ice crystals; when these crystals are small the meat resembles fresh meat on thawing.

Up to the present, experimental storage trials have, for the most part, been confined to fruits and vegetables of the temperate zones. What of the tropics and the numerous food products of excellent flavour and high nutritional value? Owing to the generosity of the Empire Marketing Board, a laboratory with cold storage facilities, has been erected at the Imperial College of Tropical Agriculture, Trinidad, for the pursuance of investigations of Panama Disease in the Gros Michel and susceptible banana varieties, and the storage of suitable, immune, possible substitutes to determine the optimum conditions of storage, whereby the successful transport and subsequent ripening to an attractive yellow colour may be effected. While the immediate use of the Low Temperature Station is concerned purely with the banana, extension in due course, so that attention may be given to other tropical commodities, seems inevitable. It must therefore be a source of encouragement to our Tropical Colonies, where an alternative industry is urgently needed to supplement a languishing staple crop, and particularly so to our West Indian possessions where, owing to the prevalence of hurricanes, the cultivation of a single perennial crop is economically unsound. The establishment of an export trade in suitable annuals would give an additional opportunity for economic development and render their position decidedly less precarious.

IMPERIAL SOIL SCIENCE BUREAU.

The Imperial Bureau of Soil Science (one of the eight Bureaux, the formation of which was recommended by the Imperial Agricultural Research Conference of 1927) commenced work on the 1st May at the Rothamsted Experimental Station. Sir John Russell, Director of Rothamsted is also the Director of the Bureau, and Dr. A. F. Joseph, lately Sudan Government Chemist, has been appointed Deputy Director. The functions of the Bureau include the collection and distribution of all research work of importance on soils to the British Empire, the assistance of research workers in the prosecution of their investigations in whatever ways it can, the bringing together of workers from different parts of the Empire (either by correspondence or in conference) interested in the same subjects, and to supply information generally which may facilitate the work of soil experts in the development of agriculture.

It is hoped that before long the Bureau will be in close touch with all soil investigators of the Empire, both at home and abroad, and that by means of information-circulars and other methods, the results of studies carried on in one part of the Empire will be made available for all. Arrangements will also be made to supply information dealing with soil investigations in foreign countries, the results of which (owing to language or other difficulties) are not readily available.

Mr. R. O. Williams' Report on Grapefruit (Price 1s. 6*d*.) based on his visit to Florida and Porto Rico has been issued as Council Paper 57, and can now be obtained on application to the Government Printer, Trinidad, Port-of-Spain, British West Indies.

LIMES AND WITHER-TIP.

Introduction and Breeding Work in Trinidad.

By R. O. Williams,
Superintendent, Royal Botanic Gardens and Assistant Botanist.

The West Indian Lime, otherwise known as *Citrus medica* var. *acida*, *Citrus limetta*, or *Citrus aurantifolia*, is a minor agricultural crop in Trinidad and Tobago, and prior to the appearance of wither-tip, had prospects of assuming considerable importance.

In 1917, wither-tip disease of limes (*Glaeosporium limetticolum*) was first recorded in Trinidad (1), and, during the next few years, quickly assumed epidemic form. It was largely responsible for considerable reduction of the island's crop, as may be seen from the following table of exports for the years 1911 to 1927 :

Year.	*Gallons.*	*Value.* £
1911	6,058	1,590
1914	5,874	2,655
1915	16,192	4,735
1916	23,940	8,079
1917	24,781	5,831
1918	29,419	7,354
1919	19,479	4,935
1920	6,157	3,266
1921	5,168	1,719
1922	nil	nil
1923	1,522	381
1924	7,505	1,015
1925	6,171	1,314
1926	7,886	1,926
1927	4,488	1,154

Various control measures, such as spraying and eradication of diseased trees, were discussed and tried, but, by the year 1920, it was evident that, owing to climatic and cultural conditions, these measures were failures. Under tropical climatic conditions, the trees make irregular and frequent flushes of growth, and spraying at short intervals is necessary to obtain any appreciable measure of control and is not an economic proposition. Cultural methods as practised in the island, facilitate the spread of the disease ; the trees being usually surrounded by bush, or sometimes partially shaded. The appearance and spread of the disease disheartened lime planters, and abandonment of lime fields, as well as the direct effects of disease, were additional causes accounting for the reduction in exports of lime products.

Soon after the appearance of the disease in Trinidad, wither-tip was also found in adjacent islands. Dominica, where the lime is a major crop, suffered most. Since, owing to the high humidity wither-tip disease caused heavy losses, which were later accentuated by "red root" disease.

The following table represents the Dominica export records for the years 1913 to 1927 :—

Year.	*Barrels of Fruit.*
1913	391,000
1914	388,000
1915	390,000
1916	384,000
1917	396,000
1918	318,000
1919	402,000
1920	369,000
1921	516,000
1922	400,000
1923	229,000
1924	424,000
1925	230,000
1926	214,000
1927	210,000

Spraying as a control measure was found impracticable, and it was decided to try to obtain, by introduction, a lime which, whilst equivalent to the West Indian lime as regards cropping power, citric acid and essential oil content, flavour, dropping characters and suitability for the green lime trade, would be resistant to wither-tip disease. The investigation was carried on more or less simultaneously by the Dominica and Trinidad Agricultural Departments.

Introduction Work.

Introductions since 1920, have been made at various times from Montserrat, the Philippine Islands, Hawaii, and Burma. The history and characters of these introduced varieties are as follows :—

Rangpur Lime.—This variety appears to have originated in India. Plants obtained from Montserrat in 1920 commenced to fruit in 1922. They are resistant to wither-tip disease but susceptible to gummosis and scab. Leaves, 2 to 3 inches long ; the stalk practically wingless. The fruit resembles a tangierene in appearance, being orange-yellow, flattened at the apex, and roundish at the base ; skin loose, rugose, sacs orange-coloured, juice abundant, seeds few and small. It does not drop when ripe. Pope, Honolulu, gives the citric acid content as 9.76 ounces per gallon ; Harcourt records a range of 10.9 to 11.8. The Rangpur lime is unsuitable in several respects as a substitute for the West Indian Lime.

Citrus hystrix P. I. No. 834. *Cabuyao.*—This lime, together with the four following varieties were received from D. Hernandez, Director of Agriculture, Manila, P. I. in 1922. It is a thorny tree with leaves about 7 inches long, including the winged petiole, which is almost as large, or sometimes larger, than the true leaf. The few trees at St. Clair have cropped heavily, but began to show signs of gummosis late in 1928. Fruit nearly 3 inches in diameter with a very thick skin, very juicy and extremely acid, the citric acid content being 10.51 ounces per gallon (Hardy) from green fruits. It is unsuitable for the green lime trade.

Citrus aurantifolia (Trinidad) P. I. No. 3670 is apparently the same as the well-known spineless variety, the West Indian lime.

Citrus aurantifolia " Everglade " P. I. No. 3669 is very like the West Indian lime but differs from it in that its flowers are all perfect and by its large clusters of rather small fruits. It is highly susceptible to wither-tip.

Citrus aurantifolia (P. I. No. 2182). Figs. 1 and 10. —Of all the introductions, this is the only one which seems even a possible substitute for the West Indian lime. It is by no means ideal, as the fruits lack the abundance of juice of the West Indian lime, and are of different flavour, rather resembling that of the lemon. Its resistance to wither-tip disease, however, and other characters, suggested it as a suitable parent for breeding work. The tree is small and spiny, with leaves 3 to 3½ inches by 1½ broad, of a yellowish-green colour, the leaf stalk almost wingless. Petals reddish outside. Fruit oblong to ellipsoidal, the apex slightly produced into an obtuse beak, 6 to 8 cm. long, 4.8 to 5.5 cm. diameter; skin rugose, more resembling a small lemon than a lime. From seeds sown in 1922, the plants began to crop in 1923, and have continued bearing throughout the year ever since. The fruits drop tardily, have less juice, more seeds, and possess a less pleasant flavour than the West Indian lime. The variety is highly resistant to wither-tip disease, and no observation of natural infection has been recorded. Some die back has been noticed. The tree suckers abundantly.

An analysis of fruit from St. Clair made by Hardy showed a citric acid content of 8.80 to 10.2 ounces per gallon and by Harcourt in Dominica [3] a citric acid content of 12.96 ounces per gallon.

Messrs. Rowntree of York reported on a sample cask of raw juice from St. Clair in 1926 as follows:—

" The juices were made up into Cordial according to our standard process, and this was carefully tested alongside our ordinary juice by experts in the Production Department. The unanimous opinion of the tasters was, that it is very different from our own standard, it lacks both acidity and characteristic lime flavour, so that it would be unwise to change over to this new juice." " We find the acid content to be 10.3 ounces, which is much below the standard of juice we are using."

As to their suitability for the green lime trade, Messrs. John Nix & Co., New York, reported as follows on a crate of limes from St. Clair:—

" The crate of limes which you state is known as " *aurantifolia* " species arrived in first class condition and although some of them are rather large, we think if they were put under two grades, specified as large and medium, that they would sell to advantage."

At the request of the Advisory Committee on Essential oils of the Imperial Institute, a sample of 121 lb. sent from St. Clair were examined, and the following report received:—

" The characters of both the expressed and distilled oils obtained from these fruits differ considerably from the ordinary West Indian products, and the oils, unfortunately, were inferior in odour to ordinary lime oils. It seems probable, however, that the freshly gathered fruit would furnish oil of much better quality."

" Owing to the condition in which the fruit arrived, due to the long period which elapsed from the time of picking, we are afraid the results of our experiments are not very conclusive. The condition of the fruit was entirely different

Expressed Oil.

	Sample.	Normal Oils.
Specific Gravity at 15/5° C	0.8657	0.877 to 0.884.
Rotation	+58.8	+32° to 40°.
Solubility in 90 per cent. alcohol ..	In 10 parts with slight cloudiness	In 4 parts to 10 parts.
Refractive Index at 25° C	1.4777	1.482 to 1.486.
Citral	2.95 per cent.	6 per cent. to 9 per cent.
Distilled Oil.		
Specific Gravity at 15° C	0.8535	0.860 to 0.870.
Rotation	+61.7	+33° to 47°.
Solubility in 90 per cent. alcohol ..	In 5 parts and more	In 2 to 5 parts and more.
Refraction Index at 25° C	1.4718	1.472 to 1.474.

LIMES AND WITHER-TIP.

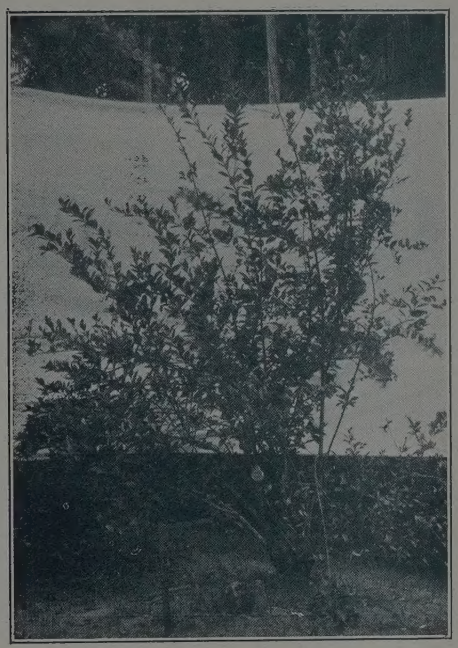

Fig. 1. *Citrus aurantifolia P. I.* 2182.

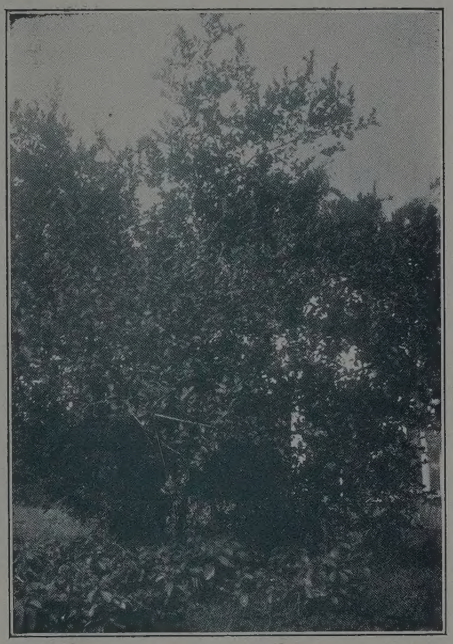

Fig. 2. *West Indian Lime.*

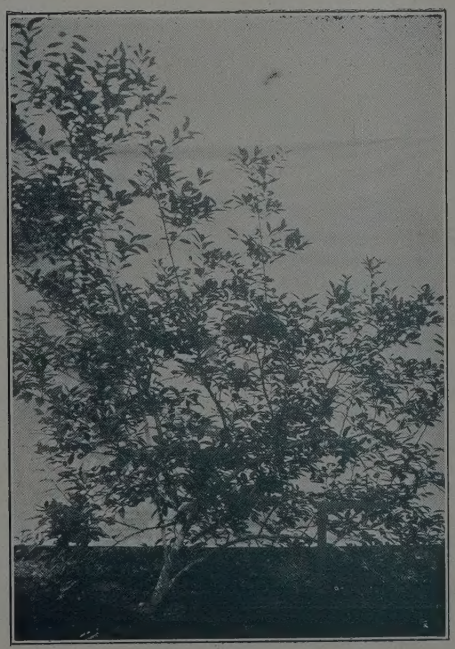

Fig. 3. *Trinidad hybrid No.* 1.

Fig. 4. *Trinidad Hybrid No.* 4.

LIMES AND WITHER-TIP.

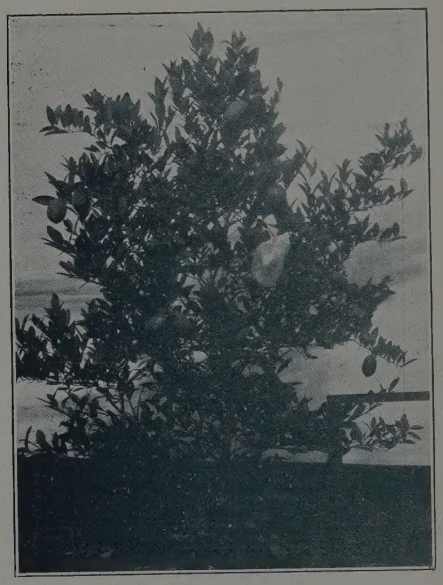

FIG. 5. *Trinidad hybrid No. 5.*

FIG. 6. *Trinidad hybrid, No. 6.*

FIG. 7. *Trinidad hybrid No. 7.*

FIG. 8. *Trinidad seedling No. 8.*

from what would obtain if the fruit were freshly picked, in addition to which, owing to the small quantity (121 lb.), the method which we found necessary to adopt was different from that which would obtain in manufacturing on a commercial scale. We were, however, able to obtain samples of both expressed and distilled oils and have made an examination of these two samples in comparison with standard West Indian products."

"The condition of the fruit with which the experiment was conducted had a very important influence on the ease of extraction and also the proportion of expressed to distilled oil. The colour of the expressed oil was also affected and would have been much lighter if the fruit had not been so ripe. The yield of juice we obtained calculated back to one ton of fruit of 2,240 lb. was 1,033 lb., which gave by separation 1 lb. 12 ounces of separated oil, and, on distilling the remainder of the juice, 2 lb. 5 ounces distilled oil. The acidity of the juice was 5.2 per cent. calculated as citric acid, which is equivalent to 84 lb. of calcium citrate, 64 per cent."

"The citric acid and calcium citrate figures are probably fairly close to what would be obtained in actual practice, but the yields of oils for the reasons stated above, are below normal. The oil possesses the following physical characters as compared with normal West Indian oils:"

"With regard to flavour and odour, both are inferior to normal oils, but this applies more to the distilled oil than to the expressed."

Citrus excelsa P. I. No. 1013 is a tall shrub with sharp stout thorns 1½ inches or more long, and the young growths blackish-purple. Leaves about 6 inches long by 2¼ broad, the petiole rather more than an inch long, with a wing 1 inch broad. Fruit borne in clusters, roundish, and somewhat pear-shaped; 3½ inches diameter. From seeds sown in 1922, the plants began to fruit in 1925. They became affected at an early age with die back and root disease, and died in 1927. De Verteuil records a citric acid content of 5.14 ounces per gallon from fruits grown in St. Clair in 1925, an analysis indicating that the fruit is of little value.

Kusaei Lime.—Seedling plants presented by Professor S. F. Ashby in 1925, grown from Hawaiian seed, commenced to fruit in 1927, but two died the same year from gummosis. The trees are also susceptible to scab, but resistant to wither-tip disease. Leaves about 3 inches long, practically wingless. Fruit, yellow, 2 to 2¼ inches diameter, the apex flattened, the base somewhat contracted. Skin loose, sacs yellow, juice abundant, seeds few and small. In general appearance, the fruit somewhat resembles a Tangierene. Pope, Honolulu, records a citric acid content of 10.80 ounces per gallon. Harcourt states it varies from 9.43 to 10.90 ounces per gallon, and that the expressed oil has a decided difference in aroma from that of the West Indian.

Burma Lime.—Three plants were received in 1926 from Dr. S. C. Harland, raised by him from seeds collected in India. They have not yet fruited, but are very similar to the West Indian lime as regards foliage characters. Leaves about 3 inches long, the petiole prominently winged. Judging from observations made at St. Clair, the trees are susceptible to wither-tip. Those planted at the Imperial College, St. Augustine, from the same source, appear to be partly *Citrus excelsa* and partly West Indian lime. The seeds, however, may have become mixed in transit.

Breeding Work.

Fifty seedlings were raised from crosses made in June, 1925, between the West Indian lime (*m*) [1] and *C. aurantifolia P. I.* 2182 (*f*) [2]. They began to fruit at 15 months old; all resemble the female parent probably owing to vegetative embryogeny, and are not further referred to in this paper.

Twenty plants were also raised from crosses made in June, 1925, between *Citrus aurantifolia P. I.* 2182 (*m*) Figs. 1 and 10 and West Indian lime (*f*) Figs. 2 and 9. They are described in detail under numbers T. 1 to T. 20. Some of them represent hybrids, others are the result of vegetative embryogeny. All are listed to show comparative characters. It is interesting to observe that the more the characters of the male parent are in evidence, the earlier they flower, and the more resistant they are to wither-tip. In those which resemble or more nearly resemble the West Indian lime, later flowering and a high susceptibility to wither-tip are observed. These seedlings were planted out, and have developed into bushes from 2½ to 11 feet high.

It is too early to draw any definite conclusions on the results of this work, but the progeny of this cross show such divergent characters that it is considered of interest to place on record the observations to date, since they may indicate the usefulness of further work along these lines.

Fifty plants each, of six of the most promising seedlings, unaffected by wither-tip, were budded on to sour orange stock, 67 of which were planted at St. Clair, Trinidad, and others distributed to the Botanic Gardens of St. Lucia and of Dominica. This was done to save time in furnishing stock trees, should any hybrid prove to be of ultimate value.

The most promising of the Trinidad hybrids is T. No. 1, and Professor Hardy has kindly made a partial examination and comparison of this and other Trinidad hybrids with both their parents. His report is given in full as an appendix. His examination shows that T. No. 1 is promising in the several required characters, especially as regards citric acid content and rind oil character. Its propagation by budding will now be extended to enable field trials and laboratory tests to be undertaken on a larger scale as early as possible.

1—Male. 2—Female.

In June, 1928, back crosses were made between the Trinidad resistant hybrids and the West Indian parent variety, and the resultant seeds sown the following November to December. Some selfed seeds were also sown at the same time.

The following number of plants from this work are now growing in pots, and will be planted out later in the year :—

Cross.	*Number of Plants.*
T. 1. (*m*) + West Indian Lime (*f*)	40
T. 4. do. do. do. ..	38
T. 5. do. do. do. ..	48
T. 6. do. do. do. ..	31
T. 7. do. do. do. ..	26
West Indian Lime (*m*) + T. 1. (*f*)	14
do. do. T. 6. do.	4
T. 1. selfed.	35
T. 5. do.	15
T. 6. do.	12
T. 7. do.	1

The back crosses, although only 6 to 9 inches high, already show considerable variation, as regards shape of leaf and spine characters.

The polyembryonic habit of Citrus seedlings often results in the production of several plants from one seed. In each case where this occurred in the 1928 batch, the seedlings were separated from each other when a week or two old, and pricked out at a distance apart in the same pot. In several cases where these are pairs or threes, one is distinctly different from the others, and the remainder resemble the female parent.

Of 147 seeds which germinated from the crosses, Trinidad hybrids (*m*) + West Indian (*f*) two produced three plants each, 34 two each and the remainder one.

The following are descriptions of the seedlings raised in 1925 :—

T. 1. Figs. 3 and 11.—Bush, 10 feet high and 8 feet spread, of loose habit. Leaves rather larger than the West Indian lime. Petals white on both sides. Commenced to fruit in 1928. Fruits ellipsoidal or more rarely oblong-ellipsoidal, the apex produced into a beak 2 to 5 mm. long, the skin smooth or slightly rugose, more resembling the West Indian lime than its male parent. No wither-tip observed from either natural infection or artificial inoculation. Two shoots were observed as apparently affected with die back. Hardy reports that in shape, colour, surface, density, juice content and citric acid content of juice, this hybrid appears to come midway between the two parents. He records a citric acid content of 9.37 ounces per gallon.

T. 2.—Died.

T. 3.—Bush, 9½ feet high and 5 feet spread. Of slender, erect growth, more resembling the West Indian lime, but the leaves rather smaller. It has not yet flowered, and is not affected with wither-tip.

T. 4. Fig 4.—Bush, 7 feet high and 7 feet spread. Leaves large and coarse. Produced in 1928 an abundance of staminate flowers with petals white on both sides. Fruit, coarse and few. No wither-tip. Not likely to be of any interest.

T. 5. Figs. 5 and 12.—Bush, 5 feet high, and 5½ feet spread. The foliage much resembles that of the male parent. Has shown no signs of wither-tip. Petals, reddish outside. Commenced to fruit in 1927. Fruit oblong or oblong-ellipsoidal, with a prominent obtusely-acute apex, 8 to 11 cm. long, 4.5 to 5.5 diameter, skin rugose. The fruit resembles a small lemon in appearance, but is inclined to be rather lacking in juice, and possesses numerous seeds. Apparently a good bearer. De Verteuil reported in 1928 a citric acid content of 7.21 ounces per gallon, and Hardy, December, 1928, 7.12 ounces per gallon.

T. 6. Figs. 6 and 12.—Bush, 6 feet high, and 6 feet spread. The foliage is very similar to that of the male parent. Petals white on both sides. Commenced to fruit in 1928. Fruit ellipsoidal, skin very smooth and shiny, the apex somewhat produced and rounded, 5.5 to 7 cm. long, 4 to 5.5 cm. diameter. Hardy reports a citric acid content of 8.40 ounces per gallon in green fruits.

T. 7. Figs. 7 and 12.—Bush, 8½ feet high, and 4½ feet spread. Of slender and erect growth ; leaves narrow, and much resembling those of the male parent. Petals white on both sides. No wither-tip. Produced a few fruits in 1928 ; these were oblong with a prominent obtusely-acute apex ; fruit 5.5 to 6 cm. long, 2.5 to 2.8 cm. diameter ; skin rugose. Hardy records a citric acid content of 8.51 ounces per gallon.

T. 8, 9, 10, 11, 13, 14, 16 and 18. Fig. 8—Bushes, 7 to 11 feet high, and 6½ to 9 feet spread. Typical West Indian lime in habit and growth. Highly susceptible to wither-tip. Commenced to flower in 1929.

T. 15.—Bush, 5 feet high, and 4 feet spread. Intermediate in character between both parents ; growth poor. Petals white on both sides. Two young fruits formed. No wither-tip.

T. 17.—Bush, 4½ feet high, and 8½ feet spread. Narrow, coarse-leafed type. Highly susceptible to wither-tip. Commenced to flower in 1929. Petals white on both sides.

T. 19.—Bush, 6 feet high, and 6½ feet spread. A broad, thick-leaved lime of the West Indian type. Highly susceptible to wither-tip. Has not yet flowered.

T. 20.—Bush, 2½ feet high, and 2 feet spread. In very poor condition. Coarse leaved type. Somewhat resembling the male parent.

Table showing susceptibility to Wither-tip Disease.

Crosses, June, 1925 *C. aurantifolia P. I.* 2182 (male) West Indian Lime (female).	Age of flowering and fruiting	Observations regarding wither-tip. disease.
True West Indian Lime 8, 9, 10, 11, 13, 14, 16, 18	Flowered in 1929	Highly susceptible.
Characters intermediate between both parents but rather favouring the West Indian Lime 1	Fruited in 1928	apparently resistant.
3	Not flowered to date	apparently resistant.
19	..	highly susceptible.
Characters intermediate between both parents but rather favouring *Citrus aurantifolia P. I.* 2182 5	Fruited in 1927	apparently resistant
6, 7, 15	Fruited in 1928	apparently resistant
20	Not flowered to date	apparently resistant
Coarse leafed seedlings resembling neither parent 4	Flowered in 1927, fruited 1928	apparently resistant.
17	Flowered in 1929	apparently resistant.

Summary.

1. Wither-tip disease has been the cause of severe losses in the lime industry in the West Indian Islands.

2. Palliative measures are not a practical means of control.

3. Plant introduction has failed to furnish a lime of the required characteristics.

4. P. I. No. 2182 crossed with West Indian lime has given interesting results, and Trinidad hybrid No. 1 shows promise of commercial value.

5. Back crossing of the resistant hybrids with their female parent has been initiated, and seedlings are now being raised.

REFERENCES.

1. *Bulletin, Dept. of Agr.*, XVI, p. 222.
2. *Annual Report, Dept. of Agr.*, 1925, p. 10.
3. *Lime Varieties in Dominica.* F. G. Harcourt, 1927.

Remarks on Appendix.

(1) *Hybrid T.* 1, in shape, size, colour, surface, density, juice content, citric acid content of juice, and refractive index of essential rind oil, appears to come midway between West Indian lime and Philippine lime.

(2) The other hybrids resemble more the Philippine lime in these various features.

(3) In the parents and in the hybrids, there appears to be a positive correlation between density and juice content of fruit, and between density of fruit and citric acid content of juice.

(4) In odour, the essential oil of the rind of *Hybrid T.* 1 appears to resemble more that of the West Indian lime than that of the Philippine lime.

(5) The small amounts of essential oils, obtained by expression from grated rind tissue, allowed only of the measurement of refractive indices by use of a refractometer; no reliable fractional distillations nor citral determinations unfortunately could be performed. It is hoped that larger numbers of fruits will be available next year, when a more detailed examination might be attempted.

APPENDIX.

Report on certain Citrus Hybrids and their parents, submitted by R. O. Williams, December, 1928.

BY F. HARDY (*Professor of Chemistry, Imperial College of Tropical Agriculture*).

	Average weight per fruit (gr.)	Average volume per fruit (cc.)	Average Sp. Gr.	Average length of fruit (cm.)	Average diam. of fruit (cm.)	Per cent. juice (gr. per 100 gr. fruit.)	Citric acid content. gr. per 100 cc. juice.	Citric acid content. oz. per gall.	Essential Oil. Odour resemblance.	Essential Oil. Sp. Gr. (at 28° C.)
(A) *Parents.*										
West Indian Lime (female)	44.5	42.5	1.048	4.5	4.4	47.2	6.19	9.90	Lime	1.469
Philippine Lime (male) No. 2182	76.9	84.6	0.908	6.3	5.1	34.7	5.50	8.80	Lemon	1.450
(B) *Hybrids.*										
Hybrid T. 1. ..	56.1	57.3	0.980	5.5	4.5	43.5	5.85	9.37	Lime	1.463
Hybrid T. 7. ..	22.5	22.0	1.022	5.0	2.9	38.5	5.32	8.51	Lime-lemon	1.444
Hybrid T. 6. ..	60.6	62.5	0.970	5.9	4.4	22.4	5.25	8.40	Lime	1.465
Hybrid T. 5. ..	115.7	128.0	0.904	8.8	5.2	21.0	4.45	7.12	Lemon	1.435

PANAMA DISEASE RESEARCH.

By DR. C. W. WARDLAW.

[*The following is a brief summary of two reports recently submitted to the Empire Marketing Board on the writer's research on Panama Disease of Bananas, at the Imperial College of Tropical Agriculture.*]

Introduction.

IT is not always that the first outbreak of a disease can be traced with certainty. This is true of Banana Wilt disease or as it is generally called, Panama Disease. While it may have made its appearance in the Western Hemisphere for the first time towards the close of last century its wide distribution in the Old World suggests a much greater antiquity. It is worthy of note that the disease became noticeable, or at least was given attention, about the same time that the banana industry had commenced its rapid expansion. The important results to date regarding Panama Disease are the outcome of work by E. F. Smith, who named the organism and indicated its capacity for growth in the vascular tissues, Ashby, who isolated the organism and carefully described it in pure culture, and Brandes, who carried out detailed inoculation experiments whereby the pathogenicity of *Fusarium cubense* was conclusively demonstrated. This important work has been repeated by Hansford and Reinking.

For all practical purposes our knowledge of Panama Disease may be briefly summarised as follows: it is a wilt disease of great severity and is associated with the parasitic soil organism, *Fusarium cubense* on suckers and roots. Several varieties are highly susceptible, but of outstanding commercial importance is the Gros Michel banana (*Musa sapientum*). While the various inoculation experiments described give a clear proof of the pathogenicity of *F. cubense* in no case do possible accessory environmental conditions, such as soil moisture, aeration, texture, acidity, humus and mineral supply, appear to have been adequately considered. The several experimental records show great uniformity of method, namely, that sterilized suckers in containers of sterilized soil were inoculated with *F. cubense* and that proofs of pathogenicity after nine or more months were obtained. Thus while the beginning and end points of the experiment are usually described in detail the records contain no information regarding intermediate events. Further, there have been no detailed experiments to test whether the attacking power of the organism is influenced by modification of the various external factors. In our present state of knowledge, then, there are two definite points of view to be considered.

1. The disease may be due entirely to internal factors, *i.e.*, to genetic constitution which determines lack of resistance to *F. cubense*.
2. The disease may be due to predisposing external factors which adversely affect the health of the plant so rendering it susceptible.

The importance of genetic constitution in this particular instance has long been known since the Canary Banana (*Musa cavendishii*) the Lacatan, and others, will grow on land where the Gros Michel has already succumbed to disease. The point to be determined is whether this well known susceptibility is constant for all external conditions or whether it is possible to delay or prevent disease by promoting the bad soil conditions under which the plant is frequently grown. On general grounds there is much to be said for both points of view.

On broad ecological grounds there are many reasons why possible external factors should receive careful consideration. Field evidence points to water supply and aeration as factors of very considerable importance. Thus there is very little disease in the Parish of St. Catherine's in Jamaica, and none in Colombia where the banana lands are irrigated, *i.e.*, where plants are growing under conditions of controlled soil moisture. On the other hand disease is of frequent occurrence on stiff soils in regions of high rainfall. Disease also occurs on open light sandy soils. Both of the latter allow of great variability in conditions of soil moisture.

On field evidence the second factor, soil aeration, is also likely to be important, since most of the untilled virgin soils, of compact alluvial or clay, suffer badly from mottling indicating lack of adequate ventilation.

In so far as *F. cubense* is mainly a wound parasite, usually entering through the cut end of the sucker, any wounding agency such as weevil-borer (*Cosmopolites sordidus*) may constitute an important accessory factor. There is thus a very considerable justification for entering on an investigation of the influence of possible external factors.

It is not necessary to discuss in detail all the implications of a test case such as this, *i.e.*, external *versus* internal factors, but it is clear that if it proves to be purely a matter of the hardihood of the plant as determined by genetic constitution then no effort should be spared to produce an immune banana to replace the Gros Michel. On the other hand should the disease prove to depend on the presence of some external soil factor susceptible of modification, then there will be a tendency in time, as determined by a number of economic factors, to make for progress in the treatment and improvement of tropical soils.

In investigating the parasitic attack of *F. cubense* on the banana there are two distinct though interrelated pathological problems, namely, root infection and sucker infection.

Root Inoculation Experiments.

The first report is concerned with root inoculation experiments on which there has been hitherto only the briefest information. Several series of experiments are described. Actively growing roots from suckers placed in ventilated moist chambers when inoculated at the tip with cultures

of *F. cubense* did not become diseased. The roots continued to grow vigorously so that the inoculum was left at some distance behind the apex. More slender roots sometimes showed a slight infection. Roots grown in unventilated moist chambers in which the carbon dioxide from the respiration of the sucker was allowed to accumulate were similarly inoculated at the apex. A different result from that recorded above was obtained. The apex became dark in colour, no further growth took place, and a basal cluster of rootlets grew out, *i.e.*, the presence of the inoculum had the same effect as root pruning. Even under these conditions the parasitism was not complete and after some days a tardy but ineffective apical growth continued, while the lateral rootlets became diseased. Several inconclusive inoculation experiments are described. These two contrasted experiments then indicate that roots maintained in a healthy state are not attacked by *F. cubense*, and that CO_2 concentration is a factor in root infection.

Roots grown in moist chambers were decapitated and inoculated with *F. cubense*. A rapid die-back of the roots took place, the youngest roots showing the most rapid infection. This is in keeping with the fact that *F. cubense* is most important as a wound parasite.

The relation of diseased rootlets to the main root was examined in some detail. As the rootlet passes through the cortex to the stele toxic substances from the fungal metabolism tend to diffuse into the cortex with lethal effects on the cells. It was found, however, that this killing of cortical tissue by diffusion of toxic secretions from the rootlets was of limited extent, and was held in check by defensive reactions on the part of the cortical cells. The latter, stimulated by dilute fungal secretions, enlarged, divided by walls at right angles to the direction of diffusion of toxic solutions, and became suberised (*i.e.*, impregnated with cork). The barrier of protective tissue thus produced had a cambiform appearance and was definitely effective in checking the further advance of either the hyphae of *F. cubense*, or their toxic secretions. Detailed examination showed that while the affected tissue was of dark colour, with hyphae in evidence, the cambiform layer and the tissues beyond were clear and translucent and free from invading hyphae. In no instance were hyphae observed to penetrate the suberised walls.

Relation of Soil Acidity to Root Infection.

In order to test whether root infection was related to soil acidity, alkalinity, or chemical composition, different soils were collected, sterilized, inoculated with heavy uniform spore suspensions of *F. cubense* and maintained at a constant state of moistness. Roots from sterilized suckers were allowed to grow down into the pots of soil. On examination of the pots after 15 days and 25 days, it was found that, although amply surrounded by *F. cubense*, the roots were without exception free from disease and quite unblemished. A definite proof was thus obtained that soil acidity and alkalinity, while very important in their effect on soil condition, are not, of themselves, direct factors in root infection. In so far as they influence soil conditions, they may, of course, be of great importance in root infection.

Variable Water-supply and Root Infection.

Suckers potted in five different soils in 10-inch pots heavily inoculated with *F. cubense* were examined after 50-90 days growth. The pots were watered daily from above and were supplied from below by standing in pans of water. The more sticky soils were intimately admixed with sand to provide ample aeration. Under such conditions of aeration and water supply, vigorous root formation takes place. A large number of roots, grown in several different soils, was thus available for examination. In all the pots, the majority of roots and rootlets were white and turgid and free from infection. Diseased roots were found under two circumstances only, namely, in the top inch of soil where occasional drying out takes place, and at the pot sides, in the top half of the pot, where again drying out and heat scorch are liable to occur. In the lower half of the pot, where there is a supply of capillary water from below the roots were uninjured, and again at the bottom where roots were growing in constant aquatic conditions there was also no disease.

In the two situations described, however, where soil moisture was liable to fluctuate, all stages of root infection were found. Here fungal penetration is closely associated with loss of turgor. Invasion of tissue varied from superficial blemishing to complete exploitation of the whole transverse plane of the root. In the latter event a slow dying back, accompanied by characteristic Panama Disease discolouration of the vascular system, was found. In roots where superficial penetration had taken place, as the result of physiological shock affecting the outermost tissues only it was found that the further advance of the hyphae towards the stele was definitely held in check by the formation of well defined suberised cambiform barriers. Diffusion of fungal secretions coupled with wound stimulus had induced reactions in the unspecialised cortical cells. These consisted of cell expansion, cell division by walls laid down at right angles to the direction of diffusion of toxic substances, and the complete suberisation of walls adjacent to the diseased tissue. Such suberised cambiform barriers were definitely effective in checking further fungal invasion, and on no occasion were hyphae or their lethal effects observed inside this defensive barrier. A large body of evidence is submitted which indicates the extent of root injury under these conditions of variable soil moisture, and points clearly to the highly reactive nature of Gros Michel roots, when they are grown under conditions conducive to vigour and health.

In the work of previous investigators it is assumed, on scanty evidence, that Gros Michel roots have only to be exposed to *F. cubense* to become diseased. But this is not so. It has frequently been observed, for example, that many of the roots of a badly diseased stool, presumably growing into soil highly infected with *F. cubense*, are free from disease. This has been found to be true even of the youngest roots produced from a badly diseased rhizome. Theoretically, according to previous assumptions, the roots should have become infected as soon as the tips came into contact with the diseased soil.

Thus both field and experimental evidence point to the fact that infection of the roots of Gros Michel by *F. cubense* is definitely conditional and is referable to at least two factors that are of first importance in tropical soils. These are soil oxidation and variable water supply. Without entering into details it will suffice to mention that most untilled compact virgin tropical soils are highly mottled and stand in need of aeration. Roots growing in such soils have to contend with defective aeration. With regard to the problem of water supply it has long been known that in regions of irrigation, *i.e.*, of controlled soil moisture, the incidence of Panama Disease is at its minimum

This investigation by no means exhausts the interesting problem of root infection. The broad conclusion which has been reached is that root infection, while important in the physiology of the plant as a whole, is of lesser importance. The fundamental problem in banana wilt is that of sucker infection.

Observations on Sucker Infection.

The second report is concerned with observations on sucker infection. In the inoculation experiments of previous investigators while definite proof of the pathogenicity of *F. cubense* to Gros Michel has been obtained, their memoirs contain little information regarding the behaviour of the attacking organism when brought into contact with its host. In none of the papers is there detailed evidence regarding the nature or rate of infection, the state of the sucker from time to time, or the influence of possible external factors. In short one is left with the impression that the sucker has only to be exposed to the organism to become diseased, and that the infection is rapid, straightforward and unimpeded. But general experience indicates that, almost without exception, the analyses and detailed study of the several important wilt diseases are both complicated and variable. These remarks are true also of Panama Disease.

In a series of preliminary experiments the writer set out to investigate the behaviour of the sucker during the early stages of inoculation and to determine the nature and rate of fungal penetration. Those experiments have proved exceedingly useful and important and have brought to light a mass of data hitherto unrecorded.

Inoculation of Suckers in moist Chambers.

Superficially sterilised Gros Michel suckers were inoculated at the cut basal end with cultures of *F. cubense*. The suckers were then placed in 4,000 cc. closed containers, kept suitably moist, and examined after 10 to 25 days. The infection thus proceeded in an atmosphere of carbon dioxide from the respiration of the suckers. It was found that a noticeable amount of penetration took place in 10 days. The tissue was affected to a depth of 1 to 1.5 cm. At this stage the infection was found to be what may for convenience be described as a *mass infection*, in contrast to its later stages when it is generally found as a *vascular infection*. Even at this early stage in some suckers it was observed that, passing out from the region of mass infection, there were vascular strands showing the characteristic yellow and red discolouration typical of Panama Disease. The region of mass infection was dark in colour, and consisted of two zones, firstly, a zone invaded by hyphae, and further in a zone where the tissue had been killed in advance of the hyphae by the diffusion of lethal by-products of fungal metabolism. The suckers of the immune Canary banana inoculated under the same conditions showed only slight infection. Further experiments showed that in both Gros Michel and Canary suckers penetration was most extensive in young suckers or in meristematic tissue. These observations were useful in indicating the extent and nature of parasitism when the suckers are in a relatively passive state. Under the same experimental conditions it was possible to induce a considerable amount of infection in young suckers of the immune Canary banana.

Reaction to Infection.

In these experiments on Gros Michel suckers it was found that after 25 days infection, the amount of mass penetration was not as great as might have been expected. Detailed observation then revealed the fact that further penetration by the fungus was being held in check by reactions developed in healthy tissue outside the zone of killing. It was found that certain cells enlarged, acquired a prism-like shape, divided by transverse walls at right angles to the direction of diffusion of toxic fungal secretions, and became suberised. In fact a protective barrier, not unlike a cambium, rendered impervious by the deposition of suberin (cork) in the outer walls, had been formed in response to fungal invasion. It is well known that such cambiform formations are very uncommon among the Monocotyledons. These changes are accompanied by the removal of storage starch from the reacting tissue.

The Influence of Fungal Secretions.

Having shown that killing takes place in advance by the diffusion of lethal secretions from hyphae growing in banana tissue, and also

that certain protective reactions take place in the suckers itself, the next stage was to test directly the effect of staled fungal solutions.

Freshly cut suckers were therefore placed in several culture solutions in which *F. cubense* had been grown for 20 days. On examination after four days it was found that the suckers had reacted to the fungal secretions present in the solutions (from which hyphae and spores had been filtered off) by forming a suberised cambiform barrier comparable to that already described. It was found that the reaction of young tissue was much greater than that of more adult tissue.

Reaction of Suckers to Wounding.

Suckers of Gros Michel, Canary (Governor), Lacatan and Red bananas were wounded at several points and planted in potting compost in which *F. cubense* and other soil fungi were present. After 10 days it was found that the suckers of all four varieties had reacted to wounding and initial fungal penetration by the formation of more or less well defined suberised cambiform barriers. Deeper fungal invasion was effectively held in check by this means. As before it was found that meristematic tissue was much more highly reactive than adult tissue, the cambiform cells having sometimes six to eight transverse divisions. A detailed comparative account of the reactions of the four varieties is given.

Penetration of *F. Cubense* into Growing Suckers.

A collection of soils in 10-inch pots covering a pH range of 5.8 to 8.1, heavily inoculated with *F. cubense*, was planted up with Gros Michel suckers. The soils were not sterilised so that in addition to *F. cubense* the normal fungal flora was present. A silt soil, on which Panama Disease notoriously occurred, with pH 6.4, was used in this experiment for purposes of comparison. As some of the other soils, were of a sticky intractable consistency about 30 per cent. of sand was intimately admixed. Suckers set in pots of these soils, with uniform daily watering, may be regarded as growing under physical conditions conducive to vigour and health. Altogether some two dozen suckers, grown under such conditions for periods of 50 to 110 days, were examined in detail. In all the soils mass invasion of the cut basal ends of the suckers was found to be limited in extent, and less in amount than that produced in closed moist chambers (where CO_2 accumulated) in one-third of the time. Vascular infection was also found to be inextensive. Again in all the suckers examined the infected tissue at the cut basal end was found to be bounded by a well defined suberised cambiform barrier. Thus in the first two to three months of exposure to *F. cubense* under the healthy conditions of pot culture the amount of penetration was singularly little. Without attempting to prejudge the final results of inoculation after six to twelve months these observations provide a definite record of the tardy initial penetration under the conditions of the experiment. These observations are not in keeping with the experimental results of Brandes who found that several young plants growing in inoculated soil were severely stunted almost from the start.

In the report a detailed account of the development of the cambiform barrier and the suberisation of the outer walls is given. The infected tissue was brown in colour, dead, and richly infested with fungal hyphae. The cambiform tissue appeared as a clear hyaline layer bounding the infected spongy tissue. Inside the cambiform layer was the normal, white, starch-filled storage tissue. The cambiform cells sometimes had eight to twelve transverse septations. The presence of suberin in the outer walls of the cambiform layer was demonstrated by various staining reactions and also by placing sections in concentrated sulphuric acid when all the cellulose tissue was dissolved away leaving behind a skeleton of suberin. The presence of suberin (*i.e.*, cork material) in the cell walls renders the latter impervious to liquids and gases. This substance therefore not only checks the further penetration of hyphae, but also prevents the further diffusion of lethal fungal secretions. In no case was penetration of the cambiform barrier by hyphae observed, or the discolouration and killing of the component cells by the diffusion of toxic secretions. The efficacy of the defensive mechanism is thus clearly proved.

It was sometimes observed, however, that cells which were in the act of expanding to form cambiform tissue were overtaken by toxic secretions before complete suberisation of the walls had taken place. Such cells were killed and afterwards invaded by hyphae. There is thus an interesting race between the protective reactions of uninvaded tissue and the diffusion of lethal secretions from infected cells further out. In some suckers it was found that two cambiform barriers were formed before the fungal invasion was completely checked.

Penetration into the Vascular Strands.

In its later stages Panama Disease is over and above all significant as a vascular disease. This is true of most wilts caused by *Fusaria*. In the sucker inoculations described in the previous sections it has been seen that the unspecialised parenchymatous tissues of cortex and stele resist the mass invasion of *F. cubense* by the development of an impervious suberised cambiform layer, the efficacy of which has been confirmed by detailed examination of a large amount of material. This barrier, however, is incomplete in so far as it is traversed by longitudinally directed vascular strands. Once hyphae gain access to the wood-vessels they may traverse long distances unimpeded by transverse septae, and it is as a vascular parasite that the fungus is usually recognised in both the sucker and aerial pseudostem.

Most authors by inference suggest that the fungus is in its most favourable surroundings in the wood-vessels, and that, in attacking a root or sucker, invasion of the xylem might be regarded, speaking teleogically, as the objective. Whether this is the true interpretation or not remains to be seen. If recent theories regarding the paucity of foodstuffs in the wood-vessels are correct, one is led to speculate on the reasons why hyphae should leave well stocked cortical cells for the scanty food supply in the vessels. It might be mentioned at this point that the hyphae in the vessels are mostly unbranched, slender and attenuated, suggestive of growth under adverse conditions. If the amount of foodstuffs in the vessels is small, it also follows that the by-products of fungal metabolism, *i.e.*, the staling products, or toxic secretions, will also be proportionally small in amount, and it becomes a question whether toxic substances from this source alone are responsible for the major wilt symptoms in the adult plant. A more likely suggestion is that mass infection, developed in the storage parenchyma, where large quantities of starch, protein and cell sap materials are available for active fungal metabolism, is the source of the considerable quantities of toxic substances required to produce the major wilt symptoms. The elimination of such regions of mass infection by the formation of protective barriers developed in suckers grown under favourable conditions is regarded as important. The experimental evidence shows that where vascular strands pass out from limited zones of mass infection, only slight and localised discolouration is the rule.

Diseased vascular strands which had passed through the cambiform layer from the small outer zone of infection were examined in detail. The presence of fungal secretions and of hyphae in the wood-vessels, and the diffusion of toxic substances from them into the adjoining vascular and ground tissue, was found to have induced a number of growth activities. Cambiform barriers developed in the ground parenchyma at right angles to the direction of diffusion from the vascular strands. In some of the vascular strands themselves additional changes were observed. The living parenchymatous cells abutting on the vessels had elongated, divided by tranverse walls, and in fact, formed a typical cambiform barrier round the diseased vessels. Suberisation took place on the walls of the cambiform layer adjacent to the vessels. Examination of other material showed that any of the unspecialised vascular parenchyma cells were capable of taking part in the formation of such cambiform barriers. The reacting cells invariably elongated parallel to the direction of diffusion from the vessels, and divided by transverse walls at right angles to the direction of diffusion. Suberisation of walls was invariably towards the source of the lethal solutions.

We thus arrive at an interesting contrast. In superficially infected roots structural and biochemical changes are brought about by living tissues to keep the fungus out of the vascular strands, while in the sucker, where hyphal penetration of the vascular strands has been effected through the cut ends, comparable changes are made by living tissues to confine the fungus and its toxic solutions within the wood-vessels.

These observations, then, go a long way towards explaining why the fungus does not escape from the wood-vessels. The importance of the physiological state of the sucker tissues, and consequently their reactive powers, which are closely related to conditions of growth, is indicated by such observations.

Inoculation of Gros Michel Suckers in Presence of Weevil-Borer (Cosmopolites Sordidus).

Twelve healthy young Gros Michel suckers were inoculated on the cut basal end with a central inoculum of *F. cubense*. These were planted in three large boxes of soils of different pH value, the original idea of the experiment being to determine whether there was any relation between the amount of infection and soil acidity. In all three boxes, after 80 days, some of the plants showed preliminary Panama Disease Wilt symptoms while others had good foliage colour, and appeared to be perfectly healthy. The suckers were taken out and examined in longitudinal section. In the healthy suckers it was found that only a shallow penetration had taken place at the inoculated end. Further infection had been checked by the formation of a well defined cambiform layer. Vascular infection was inextensive.

When the diseased suckers were examined, however, it was found that the stele showed the characteristic yellow and red vascular discolourations. These extended to the meristem and passed out into the leaf-bases. On closer examination it was observed that this well marked infection had not originated through the inoculated basal cut surface. At the latter point the fungus had effected only a comparatively shallow penetration as before, and also had been definitely held in check by a cambiform layer. A more detailed examination then showed that the major vascular infection originated at the neck of the sucker about soil level and proceeded upwards to the meristem and leaves and downwards to the basal end. In most of the suckers this was clearly proved by the fact that the downward infection had not yet reached the cut basal end. Further investigation showed that all the diseased suckers had been invaded by Weevil-borer (*Cosmopolites sordidus*). The larval burrows could be traced from the outside inwards and the disposition of tissue affected by *F. cubense* coincided with the extent of the burrowing. Apparently in these suckers the hyphae of *F. cubense* had followed the paths of the larvae. The damage caused by the latter to vascular strands and ground tissue, together with the considerable quantities of food materials made

readily available for the hyphae, would create a large zone of mass decay from which an extensive amount of vascular infection would inevitably result.

In another experiment Gros Michel suckers had been grown in pots of unsterilised soil from a badly infected area on the College grounds. The soil had been further infected by heavy spore suspension of *F. cubense*. After 115 days four pots showed characteristic external symptoms of wilt. When the suckers were examined in longitudinal section it was found that the cut basal ends were completely protected by well developed cambiform barriers, and that vascular infection had not originated from this source. The marked vascular discolouration in the middle and upper portions of the suckers was again definitely associated with larval burrows.

All varieties of bananas are liable to be attacked by weevil-borer. When the Gros Michel banana is attacked with *F. cubense* present, the result is a very effective parasitism by the fungal organism. Without elaborating this point further it is evident that the parasitism of *F. cubense* in the presence of weevil-borer merits the most careful attention.

Lateral Infection of Suckers.

As *F. cubense* is principally a wound parasite, two possible points of entry into the sucker, in addition to the cut basal end, remain to be considered. These are (*a*) the leaf bases of old leaves and (*b*) root bases exposed by trimming off roots at the time of planting.

It was found that infected leaf bases were bounded internally by a characteristic suberised barrier of cambiform tissue. Invasion through these exposed surfaces is therefore checked.

When roots are trimmed away from the sucker, each root base presents a wounded open surface, and theoretically invasion of the sucker through the vessels of the root should take place rapidly. Observations conducted on a large collection of suckers growing in infected soils, however, have shown that infection of the sucker does not take place through these points of entry, and there are therefore strong indications that some effective protective mechanism is in operation.

It has already been seen that unspecialised tissues may become structurally modified and suberised so as to prevent further fungal invasion.

The great obstacle to be overcome by the plant is the blocking of the wide wood vessels to prevent the further passage of hyphae and their toxic secretions. It was found in the root bases that this difficulty was overcome in two distinct ways, and frequently both were present in the same cross section. These were, (I) by tylosis, *i.e.*, the intrusion of living tissue through the pitted walls of the vessel and subsequent enlargement of the tyloses inside. These tyloses become closely adpressed and suberised, and prevent further penetration of hyphae or diffusion of lethal solutions; (II) by vessel collapse; dilute solutions of the fungal secretions have a stimulating action on living cells; those abutting on the vessels expand considerably and bring about a complete collapse of the vessels.

Discussion.

These reports have been concerned with a statement of facts regarding preliminary experiments on the inoculation of roots and suckers rather than with the final implications of such observations and findings. The extent of an infection which normally may take a year to run its course in the field cannot be prejudged on observations limited to the first few months of exposure to the parasitic organism. Collectively the results obtained so far show that despite the virulent parasitism attributed to *F. cubense*. inoculated suckers grown under conditions of uniform moisture and adequate aeration resist fungal invasion by defensive structural and biochemical modifications. Such growth reactions are always in definite relation to the source of infection. Where mass penetration is shallow, vascular infection has also been found to be insignificant. These observations are, of course, set down without prejudice to greater degrees of infection that may be found during later phases in the metabolism of the sucker and the life of the plant as a whole. The results obtained are simply records of the limited parasitism found when suckers are maintained under controlled conditions favourable to healthy growth.

In dealing with the influence of external factors on sucker infection at least two are indicated as being of considerable importance, to wit, carbon dioxide concentration and injurious agents such as weevil-borer.

In conclusion, while the evidence submitted in these reports indicates that the intensity of the infection and the power of the plant to react are conditioned by certain external factors, it would be unwise to prejudge final results on preliminary findings. The importance of the observations recorded lies, rather, in that they indicate the lines of research and methods that will be most profitable to follow, and at the same time they afford a definite series of criteria by which the activities of invading parasitic organisms may be gauged.

PUBLICATIONS FOR SALE.

Copies of the following publications may be obtained on application to the Editor, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

Sugar Cost Accounts ..By G. C. Skinner, Price 1s.

Experimental Error ..By E. J. Maskell, Price 1s.

The Sugar Industry of the West Indies and British Guiana, with special Reference to Trinidad ..By C. Y. Shephard, Price 2s.

ANIMAL NUTRITION.

[*Being an Informal Address given by Professor T. B. Wood*, C.B.E., M.A., F.R.S., F.I.C., *to the Trinidad Science Club on 21st February*, 1929.]

I AM alarmed at the scope of the subject on which I am asked to address you, so perhaps you will endure a few preliminary remarks. It is clearly impossible for me to cover the whole range of the subject, and I have thought rather anxiously how I am to limit my address so as to deal with that aspect of animal nutrition which will be of the greatest interest to the majority of the audience. It occurs to me that, since most of you are members of a new institution, where you are engaged in building up your schemes of research, perhaps the most interesting and profitable line I can take is to attempt to describe to you how the Animal Nutrition Institute at Cambridge originated, and how it has developed since its creation. You must pardon me if I am personal. I am afraid I cannot avoid it, as you will see before I have finished.

In 1908, Mr. Lloyd George's Government created the Development Fund "for the development of agriculture and other rural industries, including roads and fisheries." Commissioners appointed to administer the fund, after much inspection and consideration, decided to establish a number of Research Institutes, each to deal with some one branch of agricultural research. Two of these Institutes were offered by the Commissioners to Cambridge.

R. H. Biffen had just brought out Little Joss wheat, which was at once a marked success, and that brought us the Plant Breeding Institute. I had just published jointly with R. A. Berry a paper on the classification, composition and nutritive value of the mangold crop, which attracted a good deal of attention, and no doubt that brought us the Animal Nutrition Institute.

I was appointed Director of the Institute which was given the income necessary to provide staff, equipment and maintenance. I was ready with a problem to work on. Protein-rich feeding stuffs were then comparatively expensive. Emil Fischer and others had hydrolysed a number of proteins, and had shown how widely they differed in composition. F. G. Hopkins had demonstrated that deficiency in certain amino-acids lowered the biological value of a protein. It seemed to me that the Cambridge Institute could perform a service to agriculture by isolating the proteins of all the more important feeding stuffs, hydrolysing them, separating the hydrolytic products by Fischer's method, and finding in this way a scientific basis for mixing feeding stuffs. Thus, an abundance of certain amino-acids in one protein might be made to balance deficiencies in another.

We all started out along these lines. One of us, F. W. Foreman, turned out to be an exceptionally able exponent of Protein Chemistry. He succeeded in isolating, hydrolysing and separating several proteins, and introduced notable improvements in methods. However, we found the work what the Americans call a very "chronophagous" business, and what is more, it was impossible by any methods one could devise to separate from a feeding stuff more than a comparatively small proportion of its total protein content. Thus if we found that the portion separated and hydrolysed was deficient, say in tryptophane, the information was useless because the portion we could not separate might be correspondingly rich in that important constituent.

During the war, the whole situation changed. Protein-rich feeding stuffs became relatively cheap, and cereals and such-like products comparatively dear. At the same time the importance of establishing a quantitative relation between food consumed and meat, milk or work produced, was forced upon us. Whilst I was in London working in turn in the Ministry of Food, the Ministry of Agriculture and the Development Commission, I was bombarded almost daily with such questions as the following—"How much beer must be brewed to provide enough yeast for the national bread supply?"; "What would be the effect in tons of bacon of cutting off the importation of cereals from a certain European country?"; "How many tons of meat shall we lose in the United Kingdom if our supply of concentrated feeding stuffs is reduced from 11½ to 8 million tons?".

Putting all these things together, and remembering the very modified success of our pre-war protein-sparing programme, I decided that as soon as the war should end, I would divert the energies of my Colleagues from protein to the relation between food consumption and meat production.

In planning the line of attack, it seemed to me that the total energy of the ration consumed by an animal should be equal to the sum of the energy utilized for maintenance and of the energy used for production of work, meat and milk. If this is true, then it should be possible to write an equation for an animal, thus:—*energy of ration=energy used in maintenance+energy used in work.* (*i.e.*, muscular movement +energy stored in live-weight increase +energy secreted in milk +specific dynamic energy of ration, *i.e.*, energy wasted during the processes of digestion and absorption).

It seemed to me, further, that if we express the energy throughout in terms of net energy, *i.e.*, *starch equivalent*, or Armsby's *net calories*, the last term must disappear, since net energy is total energy less specific dynamic energy.

With this idea in mind, the work was divided thus:—J. W. Capstick and T. Deighton, with the assistance from time to time of research students, tackled the maintenance requirement term, using animal calorimeters where possible, and an indirect method (which I will describe later) where calorimetry failed. Capstick, with the assistance of research students, studied the

energy used in muscular movement. With the help of W. A. Wood, L. F. Newman, A. J. Codling and several analytical assistants, I studied the composition of live-weight increase, with the object of estimating the energy stored in that form under various circumstances. Finally, W. Mansfield and H. V. Garner on the University Farm began to study the energy secreted in milk. The whole project has gone surprisingly well. Capstick and Deighton have shown that the maintenance term should be divided into two parts, the first part being what physiologists call *basal metabolism, i.e.*, the energy used in performing the vital functions, such as respiration and circulation when the animal is fasting and asleep. This can be precisely written ab, where a is the animal's skin area, and b its basal metabolism per unit area per unit time. Again, a (which is difficult to measure directly), can be estimated from the live-weight by the equation $a = Kw^{\frac{2}{3}}$, where w is the live weight in *lb.*, and K is a constant, approximately = 0.053 for all farm animals. This gives a in square metres.

From their calorimetric measurements on fasting and sleeping animals, b, for adult animals, appears to be approximately 40 calories or 0.035 lb. starch equivalent per square metre per hour. In some young animals, notably the pig, it is much higher. Capstick and I have further shown that the second part of the maintenance term may be written dwe, where d is the distance through which a normal animal moves during a normal day, w is its live-weight, and e is the energy used in moving unit live-weight through unit distance.

The whole maintenance term is therefore $Kw^{\frac{2}{3}}b + dwe$. We have not yet succeeded in making direct measurements of either d or e, but we have obtained certain results which indicate that the total value of dwe is about 25 per cent. of $Kw^{\frac{2}{3}}b$. The best we can do at present is to assume, quite unscientifically, that the latter part of the term is proportional to the surface, when the maintenance term can be written $Kw^{\frac{2}{3}}m$ where m, is the maintenance requirement per square metre per unit time.

We find that the live-weight increase term can be written gc where g is the live-weight increase per unit time (1 lb. per day) and c is the weight of starch equivalent required to make 1 lb of live-weight increase. Our slaughter experiments show that quite young animals make 1 lb. increase from 1 lb. of starch equivalent, which rises with fair regularity up to four lb. of starch equivalent during the last stages of fattening of adult animals.

We have not done much work ourselves on the requirements of milk production. Fortunately, however, they are already fairly well known. Kellner, in 1911, estimated that 2.2 lb. of starch equivalent would make one gallon of average milk. The accepted figure is rather higher, namely 2.50 lb.

The full equation can now be written thus:—

$$R = Kw^{\frac{2}{3}}b + dwe + gc + vp$$

Most of the symbols have already been defined. It remains to add that R is the ration consumed, and that v = volume of milk in gallons per day, and p = weight of starch equivalent required to make one gallon of milk.

We have not yet determined experimentally the full equation, because we have at present failed to measure the term dwe, and we have no full facilities for work on milk production. We have, however, checked the simpler equation:—

$$R = Kw^{\frac{2}{3}}m + gc$$

For instance, we fed 100 sheep on a ration calculated by this equation to produce per week a live-weight increase of 2.25 lb. The actual live-weight increase produced was 2.22 lb.

We have found the above equation useful in many ways. For instance, sheep are too nervous to be used successfully for calorimetric work so we could not find their basal metabolism by that method. We found it, however, by applying the data from 32 experiments by H. E. Woodman in our laboratory, in which he had recorded food consumption, live-weight and live-weight increase during the course of digestibility determinations. We were therefore able to write 32 equations as above, and to solve them for m and c, so as to extract the fat values by the least square method. We thus obtained what has proved to be a very reliable figure for the maintenance requirement of the adult sheep.

Again, the equation makes it possible to determine the starch equivalent of dry feeding stuffs which might form the main portion of the ration. For instance, if a number of animals are fed mainly on a known weight of grain supplemented by a small ration of concentrates, and if their weights are accurately recorded, then the starch equivalent of the grain can be calculated.

I have said enough, I hope, to show that our new way of looking at animal nutrition has enabled us to establish a definite quantitative relation between food consumed and products manufactured, which is what we set out to do. Much more work has to be done before we have complete data for every activity of farm livestock, but the way is now clear.

MONTSERRAT'S TRADE IN 1928.

The year under review proved a most successful one for Montserrat from an agricultural point of view. The main crops of the Island gave record yields, surpassing all previous yields in the Island's history. The main industry, cotton, was again the Island's mainstay, 666,000 lb. of lint being shipped. This represents the satisfactory yield of 222 lb. of lint per acre. The onion crop also proved a record one, 447,602 lb. of onions being shipped. The total exports of the Island showed a substantial increase from £50,576 in 1926 to £68,753 in 1927.—(*The Vincentian*, Vol. X, No. 17.)

MEGASS.

Its value as a material for the manufacture of Paper and of Artificial Silk.

Introductory.

In an article appearing in Vol. XXVII, No. 1, of the "Bulletin of the Imperial Institute," it is stated that attention has been devoted recently in different countries to the possibility of increasing the range of materials available for the manufacture of artificial silk. Amongst materials examined during the past year at the Institute in order to determine their suitability as sources of cellulose for artificial silk, was a sample of megass forwarded from Trinidad. We reprint below the results obtained from experiments carried out at the Imperial Institute with this fibrous residue, with the object of examining the possible uses in the manufacture of paper and artificial silk. It is unlikely that the demand for megass pulp as a raw material for paper or artificial silk will ever be great. The cost is probably too high for it to compete successfully with other sources of cellulose, such as spruce.

Megass for Paper-making.

The sample consisted of fibrous chips and crushed cane in pieces of irregular size up to 5 inches in length. A large quantity of pithy matter was present, adhering to the fibrous material.

A chemical analysis was carried out on the megass as received, without any separation of the pithy matter, with the following results:

	Per cent.
Moisture	10.8
Ash	1.2
Cellulose in material as received ..	51.2
Cellulose expressed on the moisture free fibre	57.4

The lengths and diameters of the ultimate fibres were as follows:

	Length. mm.	*Diameter.* mm.
Maximum	5.0	0.0508
Minimum	0.6	0.0152
Average	1.95	0.0264

The crushed cane was reduced to pieces of approximately even size, and treated with caustic soda under conditions similar to those employed commercially for the production of paper pulp. The following results which are expressed on the material as received, were obtained:

Trial.	Caustic soda used.		Conditions of Digestion.		Parts of caustic soda consumed per 100 parts of material.	Yield of dry pulp.	
	Parts per 100 parts of material.	Parts per 100 parts of solution.	Time.	Temp.		Unbleached	Bleached.
			hours.	°C.		per cent.	per cent.
A	20	3	2	140	11.0	52	37
B	20	3	3	140	11.7	48	40

Trial A.—The conditions of this experiment were not sufficiently drastic to yield a well digested pulp. The fibrous portion of the cane was only partially attacked by the liquor, and it was necessary to employ a lengthy and drastic beating treatment in order to reduce the insufficiently digested fibre particles to a workable size, with a consequent overbeating of the better digested portion. The pulp furnished a pale brown, opaque, "rattly" paper of excellent strength, which, however, contained a large amount of imperfectly digested fibre.

The pulp bleached fairly readily to a rather dark cream colour, and furnished a paper of "rattly" character and excellent strength. The unreduced fibre particles were not affected by the bleaching treatment, but a large proportion of the cellular matter was attacked by the bleaching solution, thus causing a considerable loss in that operation.

Trial B.—The conditions of this trial were just sufficient to produce a well digested pulp, which furnished a pale greyish-brown paper of similar character and strength to that obtained in Trial A, but showing less "rattle" and greater freedom from unreduced particles. A number of fibrous specks were noticeable, probably derived from the nodes of the cane. With a light bleaching treatment the pulp furnished a very pale cream-coloured paper of similar character and strength to the unbleached paper. The small specks, however, were only partially affected by the bleaching treatment.

This sample of megass from Trinidad furnished a good yield of pulp which was easily bleached and yielded paper of excellent strength, but exhibiting the "rattly" character of paper produced from fibrous material containing pithy matter. By mechanical separation of the pith from the fibrous material it would no doubt be possible to produce paper of very good quality.

It is possible that paper of good quality could be produced from megass by the adoption of a fractional digestion process (as applied to bamboo), or by the De Vains chlorination process, which is extensively used for the production of straw pulp of good quality. The latter method would entirely eliminate unreduced fibre particles.

Megass for Artificial Silk.

Owing to the presence in the material of the pithy matter, which would be unsuitable for use in the preparation of cellulose intended for the manufacture of artificial silk, the material was subjected to mechanical treatment with a view to the separation of pith before digestion.

(A) A quantity of the megass was treated by light grinding (or rubbing) and sieving to remove the pith. In this manner approximately 33 per cent. of pithy matter was eliminated. The fibrous material was then treated with caustic soda under conditions similar to those employed commercially for the production of pulp, with the following results, which are expressed on the material as received :

Caustic soda used.		Conditions of Digestion.		Parts of caustic soda consumed per 100 parts of material.	Yield of dry bleached pulp.	
Parts per 100 parts of material.	Parts per 100 parts of solution.	Time.	Temp.		On air-dry separated material.	On original material as received.
		hours.	°C.		per cent.	per cent.
20	3	4	140	12.25	43.5	29 (approx.)

The conditions of this digestion were sufficient to yield a well reduced pulp which bleached fairly readily to a cream colour. The cellulose obtained was examined chemically as to its suitability for the manufacture of artificial silk, and was found to contain :

	Per cent.
Moisture	5.1
Calculated on the moisture-free material :	
a-Cellulose	78.75

The pulp was thus deficient in *a*-cellulose, showing that the original material required further purification.

(B) A further quantity of the megass was therefore taken and treated as follows :

(1) The air-dried material was freed as far as possible from pith by rubbing and sieving.

(2) The material was then submitted to a preliminary process of fractional digestion as follows :

(*a*) Boiled with water with continuous agitation, then filtered through a coarse sieve. This operation was repeated. This removed starches, sugars, soluble gums and other water-soluble matter, together with some more finely-divided pith.

(*b*) Boiled with 1 per cent. caustic soda. The pithy matter attached to the fibres swelled and could be fairly readily separated by agitation. This operation was repeated, and removed resins, fats, waxes, &c., together with pectins.

(*c*) A further washing in water was given, and the material finally freed from almost the whole of the remainder of the pith by a light beating treatment in the Hollander. The material thus obtained after air-drying contained 6.5 per cent. of moisture, which was approximately the same as the amount present in the original material.

This material, constituting 40 per cent. of the original untreated megass, was digested with caustic soda under the conditions given below, with the following results :

Caustic soda used.		Conditions of Digestion.		Parts of caustic soda consumed per 100 parts of material.	Treated Material. Yield of dry bleached pulp.		Original Material. Yield of dry bleached pulp.	
Parts per 100 parts of material	Parts per 100 parts of solution.	Time.	Temp.		On air-dry material.	On moisture-free material.	On air-dry material	On moisture-free material.
		hours.	°C.		per cent.	per cent.	per cent.	per cent.
20	3	3	140	7.1	63	68	24 (approx.)	26 (approx.)

The pulp, which was fairly long-fibred, bleached readily to a pale cream, and, when dry, could be fairly easily disintegrated by hand.

On examination as to its suitability for the manufacture of artificial silk, the pulp gave the following figures, which are shown in comparison

with (*a*) those recorded for bleached sulphite pulp of quality suitable for this purpose, (*b*) figures supplied by a manufacturing firm for pulp regularly used by them, and (*c*) figures recorded for commercial absorbent cotton :

		Present sample.	Figures recorded for bleached sulphite pulp of satisfactory quality.		Manufacturers' figures for wood pulp for artificial silk.	Figures for absorbent cotton.[1]
			(1)	(2)		
Moisture	per cent. ..	7.7	8 to 12	10	—	4.34
Calculated on dry material. Ash	do. ..	0.14	0.15 to 0.3	0.1 to 0.4	0.17	0.11
Calculated on dry material. α-Cellulose	do. ..	86.1	85 to 89	86 to 89	89.63	87.6
Calculated on dry material. β-Cellulose	do. ..	12.6	—	6 to 8	3.69	12.2
Calculated on dry material. γ-Cellulose	do. ..	1.3	—	3 to 5	6.63	0.12
Calculated on dry material. Copper number	.. ..	0.56 [2]	Not over 3	2 to 3	2.47 [2]	1.13 [3]
Calculated on dry material. Phloroglucinol absorption value	per cent. ..	1.19	—	—	1.03	—
Calculated on dry material. Soda absorption value	..	215	—	—	162	—
Calculated on dry material. Acetone extract	per cent. ..	0.26	0.6 to 0.7	—	—	—

(1) S. A. Manood and D. E. Cable, *Journ. Indus. Eng. Chem.*, 1922, 14, 727.
(2) Braidy's Method.
(3) Schwalbe's Method.

The foregoing figures indicate that the megass pulp prepared in Experiment B would be quite suitable for the manufacture of artificial silk. The amount of *a*-cellulose present is slightly above the minimum usually present in bleached sulphite pulp used for artificial silk production. Moreover, the quality of the pulp as shown by its copper number, phloroglucinol absorption value, and acetone extract, is very satisfactory, these values being all very low. It will be observed that the megass pulp contained a rather large amount of β-cellulose, and in this respect resembled cotton rather than sulphite wood pulp.

This investigation shows that megass, on suitable treatment, is capable of producing pulp similar in chemical composition to the wood pulp employed in the manufacture of artificial silk. The behaviour of the pulp would, however, have to be determined by manufacturing trials before a definite pronouncement could be made as to its suitability for the purpose. It will be seen that soda pulp of the requisite purity, as obtained in Experiment B, was produced only after a preliminary process of mechanical and chemical treatment, in order to separate from the fibrous portion of the megass the large amount of useless pithy material present, which constituted approximately two-thirds of the original megass. This process would probably offer little difficulty in the factory, with the employment of suitable mechanical agitators by means of which an even better separation of the pithy matter might be secured, and as a result, pulp obtained with a still higher *a*-cellulose content than that produced in the present experiments.

The yield of dry bleached pulp obtained in Trial B from the fibre (after removal of the pithy matter), *viz.*: 63 per cent. of the air-dry material, was very good, but it will be seen that this amount only represented about 24 per cent. of the original megass, whereas, on a commercial scale, spruce yields from about 45 to 50 per cent. of pulp.

AMERICAN CITRUS FRUIT.

The United States Bureau of Agricultural Economics estimates the citrus crop of the present season at 20,000,000 boxes, of which 8,000,000 boxes will be grapefruit and 12,000,000 boxes oranges, including tangerines. This is an increase on previous forecasts of 1,000,000 boxes each of oranges and grapefruit, and compares with 7,200,000 boxes of oranges and 6,500,000 boxes of grapefruit shipped last season.

While the crops of the past three seasons have been comparatively light, the number of trees of bearing age has been steadily increasing. This season there was a good setting of fruit in all sections. The storms of August and September caused a heavy loss, especially to grapefruit, and sizes of early and mid season oranges have been running smaller than usual, but production still promises to approach nearly to that of 1923-24 when shipments slightly exceeded 20,000,000 boxes.

CANE SYRUP.

We publish with this issue a Memoir on Cane Syrup by Dr. R. H. Hurst and Professor W. Scott. Copies of this Memoir, price 1s., can be obtained on application to the Editor, the Imperial College of Tropical Agriculture, Trinidad, B.W.I.

POWER ALCOHOL.

The future importance of alcohol as a fuel and as a substitute for petrol is stressed repeatedly. It is probable that alcohol will become the source of energy for the internal combustion engine when the oil fields are exhausted. It is therefore appropriate and significant that a paper entitled *Alcohol for Power Purposes* was read by Col. Sir Frederick Nathan before the Fuel Conference in London. The substance of this article is taken from that paper.

Alcohol cannot compete with petrol at its present relative price. Methods appear to be forthcoming, however, by which it may be produced cheaply and in larger quantities. Moreover, the amount of alcohol made at present is but a small fraction of that which would be required to replace the world's petrol supply. An increased production should be accompanied by a decrease in manufacturing costs and a corresponding decrease in the price of alcohol. Some fuels consisting of pure alcohol or mixtures with petrol and benzol are already on the market, but their cost is prohibitive.

There are two main processes for the manufacture of alcohol. Firstly, the fermentation process in which vegetable material such as cellulose, starch and sugars are decomposed by bacteria. Secondly, the synthetic process, in which alcohol is built up from its elements by the aid of suitable catalysts. At the present time the former process is the most important, though it is possible that when more efficient catalysts and methods of control are evolved the fermentation process will be superceded.

It is essential in the production of fermentation alcohol that the initial vegetable material should be cheap, preferably material that would otherwise be wasted. In Europe, the chief raw materials used are potatoes, mangolds and sugar beet. The agriculture in temperate climates is usually intensive and very little waste material which could be utilised is produced. The materials used are foodstuffs and the supply is seldom in large excess of the demand. Their price as raw material is therefore high. Nevertheless, Germany and France produced nearly ten million gallons of alcohol in 1926-27. In tropical countries the situation is different. Plant growth is more rapid and agriculture less intensive. More vegetable material is wasted. Crops of which the cost of growing is low may even be produced profitably solely as raw material for alcohol. The future of the fermentation process undoubtedly lies in the tropics.

The following indicates some tropical crops which may be utilised as raw material for the fermentation process. Cassava can become a valuable source of alcohol. At present it is used entirely as a foodstuff or as a source of starch. In the Gold Coast and in Queensland it has been grown specially as a raw material for alcohol. In the former place the cost of growing was too high, in the latter the experiments are continuing. Cassava is valuable, however, as a ground shade or cover crop under coconut or cocoa. Grown in these conditions the relative cost of production may be low and it may afford a means of deriving an additional income from a source that is usually neglected. Maize can be made a valuable raw material for alcohol, for the grain, the cob and the stalk can be used. At the present time its importance as a foodstuff and as a source of starch prohibits its use in that capacity.

In the Philippines, the sap of the nipah palm is fermented to produce alcohol. Originally used solely as a beverage, it is now being turned to other channels. North Borneo has large natural areas of nipah palm which can be tapped to give 3,000 gallons of sap per acre per season, producing about 200 gallons of alcohol at low cost. In Malaya, the nipah palm is grown entirely to supply sap for alcohol manufacture.

The ease with which molasses can be fermented into alcohol and the alcohol separated has made it one of the chief sources of cheap alcohol. On a large scale it can be produced very cheaply but the present demand is sufficient to maintain the high price. In Northern Queensland, alcohol for power has been successfully manufactured from waste molasses.

Sweet potato with its high starch content affords a further potential source of alcohol. At present it is grown only in sufficient quantity for food. If it could be grown as a subsidiary crop in a similar way to cassava its collection and fermentation might become profitable.

The rapid growth of tropical grasses and the quantities of waste vegetable matter produced by such crops as sisal hemp and rice, suggest that these could be utilised. Unfortunately, no single organism which will break down cellulosic material to alcohol is known. The material must therefore be first hydrolysed by digesting it with two per cent. sulphuric acid. The excess of acid is pressed out, the material is steamed under atmospheric pressure, cooled, and neutralised with lime. The wash is fermented under carefully controlled conditions. The alcohol is separated by distillation. A ton of raw material produces twenty gallons of a liquid containing ninety parts of alcohol and ten parts of acetone. This mixture is an excellent engine fuel.

Many processes have been patented for the production of alcohol from sawdust and wood. The wood must be first hydrolysed to "wood sugar" with dilute acids under pressure, or with forty per cent. hydrochloric acid. The second method produces a sixty per cent. yield of wood sugar which readily fermented to alcohol.

The future of these processes undoubtedly lies in the tropics where wood and other cellulosic material may be grown rapidly. It will probably be necessary for the fermentation processes to be performed on the estates where the raw material is obtained. Heavy charges for the transport of bulky material would thus be avoided. Molasses owes some of its importance as a source of alcohol

to the fact that it can be used on the estate where it is produced. The alcohol industry may be compared with the sugar industry. If sugar-cane were transported over large distances the freight charges would be prohibitive. Moreover in order to produce sugar profitably the process has to be on a large scale and intensively controlled. If alcohol were produced under like conditions it might become even now a serious competitor to petrol.

H. H. C.

TROPICAL FRUIT PRESERVATION.

An article by W. Spoon in *The India Rubber Journal* (Vol. LXXVII, No. 16) summarises as follows an account of experiments on the preservation of fresh East Indian fruits with latex, published in No. 43 of *Berichten van de Afdeeling Handelsmuseum van de Kon. Ver. Koloniaal Instituut.*

The experiments were made with: (*a*) ordinary untreated latex, (*b*) vulcanized latex, (*c*) "Uterex," *i.e.*, latex concentrated by the Utermark centrifugal process. The last two were tried because ordinary latex gave a very thin film, easily damaged during transit. The fruits were dipped two or three times, dried, packed and shipped to Europe in cold storage chambers. On arrival at Amsterdam, the rubber films were stripped off, and the fruits kept under observation for some time. Untreated fruits were also included in every batch as controls.

The first batch, from Medan, consisted of various kinds of "djeroek" (varieties of the lime, orange, tangerine and grape-fruit), papaws, water-melons, bread-fruit, "terong batak," "sawo manila" and "djamboe bol"; these were treated with ordinary latex and packed in coconut fibre which was later found to adhere to the rubber film and damage it, whence it is recommended that the film should be dusted with talc. The rubber film prevented the growth of mould which otherwise formed on the papaws and "djamboe," but did not retard ripening, probably owing to most of the films being damaged.

The second batch from Medan, consisting of orange and grape-fruit varieties, papaws, bread-fruit, "terong" and "sawo," were treated with vulcanised latex. The tougher rubber films so produced were much less damaged than in the first batch. Nevertheless, they retarded ripening, but it was concluded that vulcanized latex was less satisfactory than ordinary latex because it developed mould and spoilt the flavour of some of the fruits.

A third batch from Java consisted of papaws and "sawo manila" treated with concentrated latex ("Uterex") and dusted with talc. The rubber films were very little damaged during transit. As in the second batch, the films retarded ripening, but, as the fruit did not ripen properly after removing the film, no real advantage was gained. In all three batches the papaws were found very difficult to handle; without a covering they became mouldy, whereas with a rubber film the flavour always suffered.

The fourth batch, also from Java, comprised various kinds of mango, picked unripe, dipped in concentrated latex and dusted with talc. These were packed in boxes without any packing material; they arrived in Europe still unripe and with the films undamaged, but after removing the films they rapidly deteriorated without ripening. The untreated controls, in this case kept in Java, shrivelled up without ripening.

The fifth batch was similar to the fourth, except that the mangoes were picked riper, but the result was no better. This batch also included papaws and soursops, picked unripe. They were still unripe on arrival, but deteriorated and did not ripen after removing the rubber films.

From these experiments the author draws the following conclusions:—

(*a*) Concentrated latex gives a stouter, stronger film than ordinary latex; both prevent development of mould for a considerable time. A vulcanized latex film is unsuitable because it encourages mould;

(*b*) With concentrated latex, it is difficult to obtain films of the same thickness on different fruits;

(*c*) A rubber film seems to affect adversely the taste of papaws, mangoes and certain *Citrus* fruits;

(*d*) In no case does the application of a rubber film constitute a decided advantage; although it retards ripening, the fruit usually deteriorates without ripening after removing the film.

The tendency of vulcanized latex to encourage growth of mould was confirmed by tests on artificial cultures of *Penicillium* (the mould found on the fruit). Whereas ordinary latex, and especially concentrated latex, retarded mould growth, vulcanized latex had the opposite effect.

NATAL SUGAR-CANE.

Among the strains and varieties of sugar-cane giving promising results in preliminary trials for mosaic resistance at the Natal Sugar Experiment Station are P.O.J. 2714, 2725, and 2878. A single healthy stool of P.O.J. 213 from a very heavily infected field has produced almost entirely sound progeny. It is hoped that this semi-immunity will be permanent, the more so as P.O.J. 213 is also highly resistant to streak and possesses various other desirable qualities. Several unidentified varieties from local sources as well as those provisionally known as Townsend's Selection and La Mercy Yellow, are considered worthy of further testing. Of the Uba crosses, C.H. 64/21 (a cross with D. 74 from Cuba) is doing well; U.D. 1 (Uba x D. 1135 from Hawaii) has not inherited the resistance of Uba. The imported Indian varieties Co. 214, 213, 281, and 290 are stated to be flourishing under Natal conditions.—(*The Review of Applied Mycology*, Vol. VIII, Part 3.)

STUDENT INVESTIGATIONS.

The following is a list of some of the papers prepared by students while in residence at the College. These are available in the College Library for reference.

1927-1928.

N. V. ROUNCE, DIP. AGRIC. (Wye) and H. P. SMART, B.SC. (Transvaal)	Shrivelling of Pods in Theobroma Cocoa L.
H. A. PIERIS, B.A. (Cantab.) ..	..Biology of Coconut Pollen, Field Experiments Morphology of the Ovule.
G. COWAN, N.D.A., C.D.A. (Glasgow) and E. W. LEACH, B.SC. (Reading)	Variety Yield Trial of Ground-nuts together with a Study of the Flowering Mechanism.
C. L. SKIDMORE, B.SC., AGRIC. (Lond.) and J. H. PALMER, B.A. (Cantab.)	(1) Variety of Coix Lachryma-Jobi. (2) Clump Register on an Acre Plot of Grenada Giant Fig.
C. B. TAYLOR, B.SC.	..Inheritance in a Stizolobium Cross.
J. E. BRUCE, DIP. AGRIC. (Glasgow) and A. H. SAVILE, DIP. AGRIC. (Wye)	Ear-to-Row Trial of Yields from Selected Maize Crops.
H. R. HOSKING, B.SC. (Lond.) and F. E. BUCKLEY (A.R.C.S. 2nd Class)	An Investigation upon the Soya Bean in Trinidad.
T. H. NICOLL, M.A., B.SC. (Agric.)	..The Causes of Peasant Indebtedness.
W. ALLAN, B.SC.	..(1) The Distribution and Economic Status of West Indian Gryllotalpinae. (2) Notes on Laphygma Frugiperda and other Pests of Corn
O. J. VOELCKER, B.A. (Cantab.) and G. N. K. Turnbull, DIP. AGRIC. (Glasgow)	The Supply of Seed for Green Manure Crops. [in Trinidad.
M. AFZAL, B.SC. (Agric.) ..	..Studies in Inheritance in Cotton
A. H. LEWIS, B.SC. (Lond.) ..	..(1) Soil Sourness and its Amelioration. A discussion of 'Lime Requirement' and a New Method. (2) The Characterization of the Soil on a Basis of the Adsorbing
A. K. BRIANT, B.A., DIP. AGRIC. (Camb.) F. B. MARTYN, B.A. (Oxon.)	..Some Diseases of Cover Crops in Trinidad. [Complex.

COLONIAL AGRICULTURAL DEPARTMENTS.

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ST. VINCENT ..	.. *Agricultural Superintendent*	..T. P. JACKSON.
SEYCHELLES ..	..*Director of Agriculture* ..	..P. R. DUPONT.
SIERRA LEONE	..*Director of Agriculture* ..	..D. W. SCOTLAND, F.S.I., N.D.A., H.A.A.C. (DIP.).
SOMALILAND ..	..*Director of Agriculture and Geologist*..	..R. A. FARQUHARSON, M.A. (Oxon.),
TANGANYIKA TERRITORY	*Director of Agriculture* ..	..A. H. KIRBY, B.A., O.B.E. [M.SC., F.G.S.
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TRINIDAD, TOBAGO AND GRENADA	*Director of Agriculture* ..	..W. G. FREEMAN, B.SC. (Lond.), A.R.C.S., F.L.S.
UGANDA ..	..*Director of Agriculture* ..	..S. SIMPSON, C.M.G., B.SC. (Edin)., N.D.A.
VIRGIN ISLANDS	..*Curator, Botanic Gardens* ..	..J. L. ILLINGWORTH, B.A. (Cantab.).
ZANZIBAR ..	..*Director of Agriculture and Government Chemist*	V. H. KIRKHAM, B.SC. (Lond.), F.I.C., DIP. AGRIC. (Cantab.), A.I.C.

TROPICAL WORLD NOTES.

Liberia and Belgian Congo.

A paper by Mr. George C. Shattuck which was published in *The Geographical Journal* (Vol. LXXIII, No. 3), contains some interesting information with regard to the Harvard African Expedition of 1926-27 which was organized with the object of making a medical survey of Liberia and studying tropical diseases of the Belgian Congo. Liberia is believed to be about 43,000 square miles, its interior has not yet been surveyed, and such maps as exist seem to have been compiled largely from hearsay. The country is heavily forested, with the possible exception of a small area near the north-eastern border and in the neighbourhood of villages where much of the land is or has been under cultivation. Opportunity was afforded by the expedition to study diseases of the coconut palm, the rubber tree and of young quinine plants and also the parasitic diseases of wild animals, especially in the western part of the Belgian Congo, and valuable collections were made of blood sucking insects, animals, birds, reptiles and plants.

On the lower Dukwia River in swampy ground a species of Raffia grows wild in profusion, from which is obtained piassava fibre, an important export, used for making brushes and brooms. Here and there, too, oil palms are seen. Higher up the river grow the forests of large trees. Most of them are leguminous and some have pods shaped like the sole of a shoe and large enough for a giant. The branches of the larger trees are tufted with epiphytes, and vines hang from them like rigging from the mast of a ship. These features of the forest are best seen where a native rice farm has been recently hewn out, exposing them to view. Where Nature has not been disturbed curtains of vines screen the forest from sight, but above it all spreads the great green feathery dome of the silk-cotton tree, or Ceiba. From this "cotton" is made the kapok which is used for stuffing pillows.

The inhabitants of the villages near the Dukwia belong to the Basa tribe, whose huts are small, mud-walled, and thatched with palm. Rice and manihot are cultivated in abundance, and maize and bananas are grown as well. The people keep a few goats and fowls, but fowls and eggs were scarce and expensive, and goats were held at so exorbitant a price that the people evidently did not know the value of money.

The rice, which is of the dry variety, is grown on hillsides which have been cleared of forest. The crop ripens in August. The flavour of country rice is far superior to that of the best imported rice. The native women decorticate the rice by pounding it with the end of a heavy stick in a wooden mortar. Decortication is incomplete, so that the rice does not entirely lose its important accessory food factors, the vitamins.

Unless rich deposits of metal or of oil should be discovered in Liberia, which seems unlikely, the wealth needed to improve conditions and to raise standards of living must come mainly from the soil. If rubber growing develops, it is likely to absorb most of the available labour, the actual amount of which is still uncertain. Should sufficient labour be found, fruit growing, coffee planting, and cocoa raising might become important industries. Oil and coconut palms, bananas, citrus fruits, pineapples, cotton, sugar-cane, tobacco, sweet potatoes, manioc, and various other fruits and vegetables are grown for local consumption. Dry rice of excellent quality is a staple food of the native, but rice is actually imported to feed Monrovia. The prevailing ignorance is demonstrated by the neglect of existing coffee plantations, by the crudely prepared cocoa, and by the poor state of nutrition of a large proportion of the indigenous population. The climate, with its abundant rainfall and absence of prolonged drought, is remarkably favourable for agriculture, but other parts of West Africa and the Belgian Congo are far ahead of Liberia.

The native tribesman needs tools, instruction in agriculture, and opportunity to earn money. He must have greater security of tenure and must be freed from certain oppressive practices before he can be expected to improve his condition much. Roads, bridges, medical attention, and hygiene are outstanding desiderata.

* * *

Uganda.

A summary by G. W. Nye is given in *Bull. Imperial Institute*, 1928, 26, 465-471, of experimental work on cotton carried out during the first six months of 1928. Pests and diseases were practically absent with the exception of jassids. Two strains with low boll-shedding rates have been isolated. S.G. 29 is a very promising strain and is being grown in bulk for limited distribution. Sowing date experiments showed the advantage of early sowing due in this season to the very dry weather. The spacing experiments indicate the advantages of closer spacing in nearly every area in which they were conducted. A significant increase in germination was shown after treatment of the seed with sulphuric acid. Samples of seed-cotton received from cotton-producing areas are satisfactory, but give indications of deterioration of the N.17 strain in some areas owing to intercrossing and mixture of seed which is very difficult to control. A report of the main crop of cotton grown on the Serere Plantation is given.—(*The Journal of the Textile Institute*, Vol. XX, No. 4.)

As much as 57,832 tons of rubber were exported from Ceylon in 1928. The value of the rubber produced in Ceylon during that period amounted to 74,000,000 rupees, according to the Customs returns, showing a crop of 45,000,000 rupees as compared with 1927.—(*Chamber of Commerce Journal*, Vol. LVII, No. 780).

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

[*The following are abstracts of Papers presented before the Division of Sugar Chemistry of the American Chemical Society, Columbus, Ohio, 29th April to 3rd May,* 1929.]

Adjustment of Acidity of Cane Molasses Fermentations.

F. M. HILDEBRANDT.

In producing alcohol from cane molasses by fermentation, it is necessary to add acid to the diluted molasses in order to secure the maximum yield. It is known that the quantity of acid necessary differs with various types of molasses and even with successive shipments of a single type. Experiments show that the maximum yield is obtained when sufficient acid is added so that there is no tendency for the pH of the fermentation solution to drift toward the acid side during the fermentation.

* * *

Experimental Application of Automatic pH Recorders to Sugar Refinery Alkalinity Control.

A. L. HOLVEN.

The possibility of replacing colorimetric hydrogen-ion control of sugar refinery products by a centralized automatic control based on pH recorders has been investigated. The chief obstacle to such an application is the lack of a suitable continuously indicating electrode. While the bare wire tungsten electrode in combination with a calomel half cell appeared the most promising of a number of combinations tested in various refinery products, this electrode proved to have the following objectionable characteristics :—

1. Calibration varies with variation of composition of sugar product under control.
2. Not readily interchangeable, because of individual differences of characteristics.
3. Lack of permanence.
4. Sensitiveness toward poisoning.

Until a more reliable type of indicating electrode, requiring fewer replacements and less attention, is developed, the general application of pH recorders to refinery alkalinity control appears impractical.

* * *

The Determination of Gums in Beet Sugar Molasses and Other Products.

A. R. CHOPPIN AND JAMES R. WITHROW.

The hydrochloric acid-alcohol method for the determination of gums in sugar products as given by Ruff and Withrow (*Journal of Industrial and Engineering Chemistry*, Vol. XIV, 1131 (1922)) gives very satisfactory results with cane sugar products. Some difficulty has been experienced in industry in applying the method to beet sugar products. The present work was designed to discover the bases, if any, and to overcome these objections and limitations, where possible. The chief difficulty we have found to be one of acid concentration. In low acid concentration the gums and other products precipitated from the beet sugar molasses by the method above were themselves a syrupy mass which adhered to the precipitation vessel and could not be transferred to the filter. No such difficulty was encountered in cane sugar products. The ash precipitated with the gums was also high. This is probably due to the high calcium salt content of the beet products. The factors which influence the accuracy of the method are acid concentration, alcohol concentration, kind of alcohol used for precipitation, time of standing after precipitation, time and temperature of drying and igniting, &c. These factors are discussed in the paper.

* * *

Ash and Electrical Conductivity of Syrups and Molasses Derived from the Sugar-Cane.

F. W. ZERMAN AND LOUIS SETTLER.

The per cent. of ash in various types of molasses produced in the raw cane sugar factory can be calculated by the same formula that was previously developed for raw cane sugars, namely, $0.0001757\ (9.13K+1935-K_1)$, provided that 0.05 grams of molasses plus 4.5 grams of pure sucrose is used per 100 ml. of solution, and the final result multiplied by 10, marring the factor in the formula 0.001757. K is the specific conductance $\times 10^6$ of the solution itself, and K_1 that of the solution acidified with 0.25 normal hydrochloric acid at the rate of 5 ml. acid added to 200 ml. of solution.

If the addition of pure sucrose is omitted, the factor must be changed to 0.001640. The same formulas also hold approximately for cane syrups, but for more accurate results they must be slightly modified. For refinery syrups the factors are considerably lower than for the products of the raw sugar factory. Filtered syrups require the lowest factors, 0.001647 with added sucrose, and 0.001351 without sucrose. For unfiltered syrups the factors are 0.001662, and 0.001566 respectively, and for final syrups they range from 0.001700 to 0.001731, and from 0.001590 to 0.001622 respectively, varying with the refinery by which the syrups are produced. The formula gives more widely applicable and generally more accurate results than the C ratio method, the same as was observed in the case of raw sugars. Conductometric titrations with alkali have shown that the differences in the factors shown above are probably due to the effect of bone black which appears to change the relative proportions of the cations in the salts present. This question is being further studied to devise a second correction which will result in a formula applicable to all products, whether treated with bone black or not.—(*La Planta*, Vol. LXXXII, No. 19, p. 365.)

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

Some Recent Work on Forest Soils.

East Norway.—(H. Glömme, Norweg. For. Res. Serv. III, 1, 1928; *Proc. Intern. Soc. Soil Sci.*, IV, 1, 1929, p. 97.)

The investigations mainly aimed at ascertaining the conditions and nature of the E. Norwegian forest soils, with particular regard to the surface organic matter. As a result, it has been found that there is a close connection between the state of the organic matter and the composition of the forest and of the ground vegetation. Each affects the other; soil conditions determine what kinds of plants will grow; plants in turn influence the formation of humus. The most unfavourable humus has arisen from markedly acidic organic material, poor in lime and nitrogen, and derived from pine-needles, heather, tree stumps, lichens and mosses. The conversion of this material into humus proceeds very slowly; the chief decomposing agents are fungi, and the action of these increases the acidity. Residues of grassy and herbaceous plants yield a more humified and less acid type of humus. They break down much more quickly, the organisms controlling this change leading to a lower degree of acidity.

The great influence which the original plant-material exerts on the character of the humus produced may be modified, however, by other circumstances. Thus, the process of conversion is greatly favoured by mineral soil material that is rich in bases. Active underground water movement also favours the best type of organic transformation. Hence, the most satisfactory end-product (mould) is found in well-drained valleys and on steep slopes. In general, the conversion of organic matter has proceeded most rapidly and favourably on sloping ground rather than on horizontal land.

Below the surface soil, unweathered rock occurs in E. Norway at a depth of between 1½ to 3 feet. The soil profile is distinguishable to within a distance of 4 to 8 inches from this unweathered substratum. During the development of the profile, reaction conditions are profoundly altered. The main type of profile over the area studied is podsolic, the reaction of the top leached layers being highly acidic (pH 3.5). In some parts of the country, where rainfall is low, a different profile is developed. Here the upper soil layers show some salt accumulation, and are very much less acidic. Between the extreme types, intermediate, brown-soil, profiles occur. Here the reaction variations are irregular.

As regards the reaction of the surface humic layers, the most highly acidic reactions are found in the "rawest" material (presumably that least humified), whose power of fixing bases is high. Nevertheless, favourable humus may also show distinctly acidic reactions, *e.g.*, pH 4.0. The reaction of the surface humic layers is not constant. It may change markedly in a relatively short time through changes in the composition of the forest and ground vegetation. When plant residues decompose under humid conditions and in deep shade, the degree of acidity rapidly increases. This change is particularly marked in woody material poor in mineral bases and in nitrogen. Maximum acidity is attained in typical "raw" humus. During the conversion of this substance into mould, the degree of acidity is materially lessened.

Several methods are known to foresters for inducing the conversion of "raw" humus into favourable humus in the forest. One is by making complete clearings; another, by making small openings for renewal by burning; another, by intermixing foliferous trees; and another, by covering the soil with branches. The most effective means of all, however, is to develop a type of forest in relation to existing soil conditions, in such a way that the formation of a favourable humus follows naturally.

* * *

Iron and Manganese Content of Feeding Stuffs.

The presence of small quantities of such elements as iron and manganese in most healthy animal and plant tissues suggests that they may be desirable if not essential for normal metabolism. It has been shown that the growth of dogs and rats fed on a manganese free diet is increased by the addition of small quantities of that element. An increase in the manganese added beyond an optimum amount retards the growth. In spite of a wide appreciation of these facts very few analyses of feeding stuffs include an estimation of the iron and manganese content.

The following analyses have been selected from a series of fifty-four made by J. T. Skinner and W. H. Peterson (*Journ. Biol. Chem.*, LXXIX, 679). They found large variations in different samples of the same feeding stuff :—

Feeding Stuff.	Per cent. Iron in dry matter.	Per cent. Manganese in dry matter.
	mg. per kg.	mg. per kg.
Alfalfa hay, first cutting	174.7	71.2
do. second cutting	242.8	46.0
Coconut oil meal ..	750.0	87.0
Corn, yellow ..	44.8	5.4
do. silage ..	362.9	34.8
Cottonseed meal ..	53.9	19.9
Ivory nut meal ..	465.0	16.8
Rice, Brewers' ..	11.0	16.8
do. polished ..	8.9	12.0
Sorghum fodder ..	54.3	41.1
Soy bean seed ..	59.5	29.5
do. hay ..	304.0	84.1

LIMES AND WITHER-TIP.

Fig. 9. *West Indian Lime.*

Fig. 10. *Citrus aurantifolia P. I.* 2182.

LIMES AND WITHER-TIP.

FIG 11. *Trinidad hybrid No. 1 (centre) and its two parents. Citrus aurantifolia P. I. 2182 (right) and West Indian lime (left).*

FIG. 12. *Three Trinidad hybrids. Citrus aurantifolia P. I. 2182 (male) and West Indian Lime (female).*

REVIEWS.

Report on the Potaro-Ireng District of British Guiana. By S. Bracewell, *Argosy Co.*, Georgetown, 1927.

This Report describes a geological survey of the Potaro River area, and forms a continuation of that described by Mr. Conolly on the Mazaruni-Puruni area. In comparison with other diamond-iferous districts in British Guiana, the Potaro area is easy of access. Besides diamonds, gold and palladium have been discovered. The wide though sparse occurrence of a new mineral containing palladium, rhodium, platinum and mercury, suggests a distant source, probably in the basic intrusive igneous rocks of the Pakaraima Mountains.

F. H.

* * *

The Conduct of Field Experiments. By R. O. Iliffe and B. Viswa Nath. Department of Agriculture, Madras, pp. 51.

The foreword to this pamphlet states that it was prepared, for the benefit of officers of the Madras Agricultural Department, in order to deal with modern methods of experimentation. The value to a large agricultural department of a clear exposition of the principles of modern field trials and their application to local problems and conditions can hardly be doubted. The present pamphlet cannot, however, be recommended. The practical recommendations as to choice and treatment of land, size and shape of plot, harvesting, &c., will probably be found useful in Madras. The discussion of the principles of planning and analysing field trials is less satisfactory.

R. A. Fisher's method of 'randomised blocks' has a short paragraph, but has clearly not been understood, and there is no recognition of the fact that a valid estimate of error is only possible when the uncontrolled plot variation is distributed at random among the varieties or treatment compared. Some of the field plans recommended are in complete violation of this principle.

The discussion of the theory of probability and of the application of tests of significance to experimental results is similarly misleading. The authors assert that the average value obtained from a small number of results is "far removed from its most probable value," and that the object of submitting results to mathematical analysis is "to ascertain this most probable value." Fortunately the authors make no attempt to ascertain this value that is more probable than the mean.

In discussing the initiation of experiments the authors several times repeat the statement, that only one factor should be studied at a time, and more specifically that each separate factor should be studied in a separate experiment. The investigation of some very important problems of agriculture, namely, the interaction of different factors, *e.g.*: variety and spacing or manuring, is thus arbitrarily excluded from the field of experimentation. Nor is any hint given of how to deal with differences in response of variety or of manurial treatments in different seasons.

Fortunately references are given at the end of the pamphlet to a number of important papers, notably by Student, Fisher, and Engledow and Yule, and the reader who consults the references may get back on to the right track.

The pamphlet includes a table of logarithms but has a quite inadequate table of squares and square roots and no table of probabilities.

E. J. M.

BOOKS RECEIVED.

We have to acknowledge the receipt of the following books:—

AGRICULTURE.

Bean Culture. E.V. Hardenburg. *The Macmillan Co.*, p. 238, illustrations 40, 12*s.* 6*d.*

BOTANY.

The Plant in Relation to Water. N. A Maximov. *G. Allen & Unwin* (2 copies), p. 452 illustrations 46, 21*s.*

ECONOMICS.

Forced Labour. *International Labour Office, Geneva*, p. 320.

Commerce of South America. C. F. Jones, *Ginn & Co.*, p. 584, illustrations 204, 15*s.*

Great Britain from Adam Smith to the Present Day. C. R. Fay. *Longmans Green & Co., Ltd.* p. 558, map, 12*s.* 6*d.*

GENERAL.

The Malay Peninsula and Archipelago. Gibson Ashley. *J. M. Dent & Sons.*, p. 236, illustrated, 5*s.*

AGRICULTURAL EXCURSION.

On Wednesday, 1st May, the last agricultural excursion of the Session took place, to the nurseries of the Trinidad Department of Agriculture at St. Clair Experiment Station. After inspecting the general nurseries, where large numbers of economic plants are propagated annually for distribution, and where budding of cacao and avocado was demonstrated, the party devoted most of its attention to the work with Citrus fruits.

In the Citrus variety plot, treatment of bearing trees affected with gummosis, by inarching of sour orange saplings, above the diseased area, was explained. Sour orange seed-beds, and the nursery plots where older plants were being budded with grape-fruit came next, and the staking and training of the young grape-fruit trees. Mr. R. O. Williams then exhibited some interesting seedling limes, the latest generations from certain crosses made by him in an attempt to breed a lime similar to the West Indian but immune to "wither-tip" disease. These seedlings illustrated very well the complications introduced into Citrus genetics by the occurrence of polyembryony.

Our thanks are due to the Director of Agriculture and to Mr. Williams for an interesting and instructive morning.

Mr. W. G. FREEMAN, B.Sc., A.R.C.S., F.L.S.

An Appreciation.

Mr. Freeman, preparatory to his retirement from the Trinidad Department of Agriculture with which he has been associated for the last eighteen years, left the Colony for New York on 4th June, and it is understood that at the end of two months' leave, he will take up an appointment in London at the Imperial Institute. As an agricultural scientist, Mr. Freeman has had a long and successful career under the Colonial Office, and has, for varying periods, served with distinction in different parts of the Empire. In 1896 he was Private Assistant to the Director, Royal Botanic Gardens, Ceylon, in 1897, Demonstrator in Botany at the Royal College of Science, London, and in 1900 Scientific Assistant to the Imperial Department of Agriculture for the West Indies. In 1903 he returned to London as Superintendent of the Colonial Economic Collections at the Imperial Institute and at the Colonial Office, was also in charge of the African Tropical Service Course. In 1904 he visited Nigeria on special service. In 1911 he was appointed Government Botanist and Superintendent of the Boyal Botanic Gardens, Trinidad, and in 1917, Director of Agriculture and Registrar of the Agricultural Credit Societies. Mr. Freeman whose activities were very varied, will chiefly be remembered in Trinidad by the unique cacao experiments which were carried out under his direction at River Estate, and by his work in connection with the establishment of agricultural credit societies in this Island and in Tobago. His wide knowledge and experience of the tropics earned him a place on many important bodies in the Colony. He was a prolific writer and the author, and, in some cases, the joint author, of valuable books and papers on tropical agriculture and botany, his most recent contribution being "The useful and Ornamental Plants of Trinidad and Tobago" which he and Mr. R. O. Williams compiled together. Mr. Freeman was also for three years in charge of the *Agricultural News* and of the *West Indian Bulletin*, and later became one of the Editors of *Science Progress* when this publication was being revised.

As Governor and member of its Advisory Council, Mr. Freeman has been associated with the Imperial College from its inception, and during his regime very cordial relations were maintained between the Department and the College. In another direction, in his capacity as Chairman of the Froghopper Investigation Committee he was in intimate touch with the research officers of the College, and it is partly due to his tact and ability in handling this Committee that this investigation has been able to produce such important results. He was also the first President of the Trinidad Science Club. Mr. Freeman's many-sided knowledge, and wide interests; his administrative ability, tact and wise counsel were recognised by all those who came in contact with him, and we wish him the best of health and a further continued spell of useful activity in the new work which he is undertaking for the Imperial Institute in London.

G. E.

COLLEGE NEWS.

A meeting of the Trinidad Science Club was held on 23rd May, when Dr. L. P. McGuire lectured on "Cold Storage Problems."

* * *

Our thanks are due to the Caroni Sugar Estates, Ltd., for their generous gift of some very useful cane planting material of the variety St. Croix 12/4.

* * *

Dr. C. W. Wardlaw, Pathologist to the College Banana Research Station, sailed by s.s. *Lady Nelson* for St. Lucia on 19th June, accompanied by Mrs. Wardlaw.

* * *

Mr. A. L. Baker, who is returning to England at the end of three years' service at the College as Lecturer in Agriculture, sailed for New York by s.s. *Vauban* on 18th June. Mr. G. Wright, Lecturer in Economics, sailed by the same opportunity.

* * *

Our thanks are due to Mr. S. W. Braggins, Superintendent of the famous gardens at La Mortola, Ventimiglia, Italy, for his welcome gift of thirty-four varieties of citrus seed for experimental purposes. The gardens are the property of Mr. Cecil Hanbury, M.P., one of the Governors of the College.

* * *

Amongst recent visitors to the College were Mr. Leon M. Estabrook, Agricultural Commissioner, Bureau of Agricultural Economics, United States Department of Agriculture, Mr. J. N. Oliphant, Conservator of Forests, British Honduras, Mr. G. McGowan, Editor of the *Trinidad Guardian*, and Messrs. L. H. Gardiner and D. Domian.

* * *

The Principal and Mrs. Evans, Mr. R. C. Wood, Professor of Agriculture, and Miss Wood, sailed for England by s.s. *Bayano* on 14th June. Mr. H. A. Ballou, Professor of Zoology and Entomology and Commissioner of Agriculture for the West Indies, will be Acting Principal during Mr. Evans' absence. Mr. J. Davies, Assistant Sugar Technologist, sailed by the same opportunity for three months' leave of absence.

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The following members of the College Staff sailed for England by s.s. *Coronado* on 31st May, for four months' leave of absence: Mr. C. Y. Shephard, Professor of Economics, Mr. H. H. Croucher, Lecturer in Chemistry and Soil Science, and Mr. R. E. Hunter, Lecturer in Botany, who was accompanied by Mrs. Hunter. Sir Francis and Lady Watts sailed by the same opportunity and will not return to Trinidad until the end of next year, as it is their intention to spend the winter months in Mauritius.

On Wednesday, 29th May, a cricket match was played between the College Staff and Students, which ended after an exciting finish, in a draw, each side scoring 158 runs. Every available member of the Staff who could get away from his official duties and hold a bat turned out, and it was by the extremely cautious play of a last minute reserve who had been blissfully contemplating the progress of the match, not knowing that he would be called upon to perform, that the Staff emerged unbeaten. Much spectacular play on both sides was witnessed, and amongst the outstanding events of the afternoon must be mentioned the magnificent bowling of the Professor of Agriculture, who distinguished himself by taking four wickets and dismissing the two star student batsmen in the last over, for ducks. The top scorer on the Staff side created somewhat of a sensation by turning out in shirt sleeves and a pair of flashy braces which he later aptly described as his working clothes. This "accoutrement," however, did not prevent him from punishing the bowling in a masterly fashion. The match was contested throughout in a most sporting manner and thoroughly enjoyed by all those who took part.

On the same day the students entertained the Staff to dinner in the Milner Hostel, and a most convivial evening resulted. When the time for speeches came Captain Wingate, as Chairman of the Amalgamated Clubs welcomed the Principal and Staff and expressed his appreciation on behalf of the students for what had been done for them during their stay in Trinidad, suggesting, in his concluding remarks that steps should be taken to arrange a reunion dinner in London.

In reply, the Principal thanked the students for their very generous hospitality, which had been greatly appreciated by the members of the Staff and himself, and informed them that steps had already been taken by the Academic Board with regard to arranging a reunion dinner. In his valedictory message to the students he spoke encouragingly of the College and of the functions and responsibilities of those who were shortly going to fill posts in different parts of the Empire. Both speeches were loudly applauded and the toasts drunk to the strains of "He is a jolly good fellow." Of the other speeches Professor Briton-Jones referred to the students' prowess in the field of sport, Mr. Leach denied the charge of serious-mindedness laid against the students, Dr. McGuire spoke about "corpses," Professor Shephard's peroration was tinged with his usual caustic wit, while Mr. Corbin was unfortunately inaudible. The assembly then rose and adjourned to the Combination room where they successfully proceeded to display their vocal talent, and thus concluded a most enjoyable evening.

The Editor will be pleased to send a gratuitous specimen copy of *Tropical Agriculture*, post free, to anyone interested in tropical development.

Mr. D. H. BROWN.

We extend a cordial welcome to Mr. D. H. Brown who arrived in Trinidad on 2nd June, by the s.s. *Cavina*, to join the staff of the College as Lecturer in Agriculture a post which is shortly to be vacated by Mr. A. L. Baker, and to act as Assistant to the Professor of Agriculture. Mr. Brown was educated at Wye Agricultural College, where he gained the College Certificate of Agriculture in 1922 and where he afterwards became Lecturer in General Agriculture and Farm Costings from 1923-1927. He was appointed to the Colonial Agricultural Service in 1927, being posted to Nigeria, and has since served as Superintendent of Agriculture in that Colony having been stationed at the Agricultural Station of Moor Plantation, Ibadan. Mr. Brown's appointment is the first under the new arrangement with the Colonial Office whereby an agricultural officer already in service with one of the tropical Colonial Departments is to be seconded for a period of two years for service at the Imperial College of Tropical Agriculture.

Mr. G. A. JONES.

The Governing Body of the Imperial College of Tropical Agriculture have appointed Mr. G. A. Jones to be Assistant Commissioner of Agriculture for the West Indies as from 1st July. Mr. Jones, who was educated at Bangor University, Wales, where he obtained the Diploma in Agriculture with 1st class honours in Agriculture, has had a long and successful career in the West Indies. Starting first on a sugar estate in Antigua in 1908, he later acted as Science Master at the Antigua Grammar School. From 1909 to 1919 he was Assistant Curator and Assistant Chemist, Dominica, from 1917 to 1918 seconded on War work and in 1919 appointed a member of the Staff of the Ste. Madeleine Sugar Company, Trinidad, where he has for several years, in the capacity of General Field Manager, been in charge of field experiments with sugar-cane and of the co-operative societies which have had a large membership among cane farmers in the Ste. Madeleine district. In 1926 Mr. Jones visited Porto Rico and made exhaustive inquiries into the sugar industry of that Island. In 1927 he was selected to represent Trinidad at the Imperial Agricultural Conference. He is a member of the Board of Agriculture, Trinidad, the Cane Farming Standing Committee and of the Scientific Committee of the Froghopper Investigation Committee. It is expected that a large part of Mr. Jones' time will be spent in travelling among the Leeward and Windward Islands, where he will advise Agricultural Officers and maintain active contact between the local departments and the specialist officers on the College Staff. Mr. Jones' expert knowledge of sugar cane cultivation and of the working of the local Agricultural Departments should make his appointment particularly acceptable to the Governments and planters in the several islands where his services will be available.

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.*]

Sugar.—Prices on the Home Markets have ranged as follows (*c.i.f.* per cwt.)

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
9th May	8	10½	12	8¼
17th May	8	9¾	12	7½
23rd May	8	6	12	3
30th May	8	4¼	12	1½
1st June	8	3	12	0
7th June	8	0	11	9

A depressing atmosphere continues to envelop sugar markets generally and prices are weaker. There is, according to *Messrs. C. Czarnikow, Ltd.*, very little evidence of any real confidence amongst the Trade at the moment; the commodity is an exceedingly cheap article of food and at its present level increasing resistance may be met with from holders. The present period of depression, however, must in the long run have the effect of slowing up the rate of increase in production in those countries which are forced to seek a market for practically the whole or part of their production, whilst on the other hand, an equally natural consequence of low prices is an acceleration in the expansion of consumption, which is already in evidence in many countries where official returns are obtainable and in the Far East. It is to this factor which the market must look for any future improvement in prices as there is little indication at present of any limitation of production.

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Cotton.—There is a limited demand for West Indian Sea Island and prices are firm at fair 23*d.*, fine 27.50*d.*, and extra fine 38*d.*—(*The West India Committee Circular*, Vol. XLIV, No. 799.)

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Cocoa.—It would appear that the weakness in the cocoa market has been more apparent than real. Lack of confidence owing to high money rates and the apprehension of possible unfavourable developments in the economic and political situation in Europe have had more influence on the market than the actual facts relating to the position of supplies. It is true that stocks are very much heavier at the present time than ever before, but, supplies will be very light for several months now and this accumulation of stocks should begin materially to decrease. —(*By courtesy of Cocoa Planters' Association, Trinidad.*)

Coffee—Brazilian coffee is rather flat but good Kenya and Costa Rica coffee sells very steadily. Stocks are 426,000 cwt., against 380,000 cwt. a year ago. A good coffee crop in Brazil is predicted, and a syndicate is said to have arranged for the surplus of old crop to be placed in Europe and the Near East at temptingly low prices. There is good sale for any coffee of really fine quality but total consumption is disappointing.—Fine Jamaica Blue Mountain has been worth from 230*s.* to 240*s.* per cwt. and good ordinary 105*s.*—(*The Times Trade and Engineering Supplement*, Vol. XXIV, Nos. 567 and 568.)

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Tea—The consumption of tea has been stimluated by the repeal of the duty. Averages for the week preceding Whitsuntide were Ceylon 20.27*d.*, Assam 18.95*d.*, Java 13.28*d.*, Sumatra 15.74*d.* and Nyasaland 11.48*d.* Total sales at the London auctions up to Whitsuntide have been 1,497,000 packages, against 1,567,000 in the preceding season. Total sales have averaged 18.17*d.* per lb., against 16.92*d.* per lb. last year. The rise has been marked in Ceylon and India tea, and in Sumatra, but not in Java or Nyasaland. China tea is selling well at full prices.—(*Times Trade and Engineering Supplement*, Vol. XXIV, No. 568.)

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Rubber.—Quotations for Plantation Sheet have ranged as follows: 9th May, 10½*d.*; 13th May, 11*d.*; 21st May, 11¾*d.*; 23rd May, 11*d.*; 29th May, 10¾*d.*; 31st May, 10⅝*d.*; 7th June, 10⅝*d.* According to *Messrs. Symington and Sinclair* the better tone in the Market seems to be due to a realisation that the accumulations in Malaya and Ceylon are now disposed of, and that from now on, considerably smaller shipments will be coming forward from these countries. The heavy supplies which had been coming forward had perhaps an unduly depressing effect on the market, but with increasing consumption the outlook for the future is steadily though gradually brighter.

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Copra.—Copra is an idle market; West Indian *f.m.s.* is valued at £22 2*s.* 6*d.*, less ½ per cent. *c.i.f.* London or Rotterdam.—(*The West India Committee Circular*, Vol. XLIV, No. 799.)

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Bananas—Jamaicas continue in fair demand, with the price to wholesalers lower at £19 per ton; the price to retailers has been reduced to 9*d.* per dozen (carriage extra). Brazilians are lower at £19 per ton, delivered nearest railway station, and in good demand.—(*The West India Committee Circular*, Vol. XLIV, No. 799.)

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Lime Products.—*Lime Oil.* Handpressed continues scarce and in demand with the value quite nominal. Distilled is firmly held but buyers are holding off. *Lime Juice.* Concentrated is dearer with a small business at £28. Offers of new crop are wanted. Some business has been done in Raw at 4*s.* 6*d.* per gallon and supplies are very small.—(*The West India Committee Circular*, Vol. XLIV, No. 799.)